Senator George J. Mitchell Center
Annual Technical Report
FY 2013

Introduction

Introduction

Maine is fortunate in being a relatively water-rich state with extensive surface water and groundwater resources. These water resources are essential to the regional economy in terms of tourism, industry, and ecosystem services. The state is not without water resources concerns due to spring flooding, sea-level change, urbanization, stormwater, endangered aquatic species, and arsenic in drinking water. It is an on-going process to identify, understand, and solve the problems encountered by resource managers. The Maine Water Resources Research Institute contributes to solutions by being the primary independent source of new knowledge in the state. We sustain water science in the state through the support of research, graduate studies, and outreach.

The Maine Water Resources Research Institute provides fundamental and essential functions, which would not exist without explicit Congressional authorization and appropriations. The federal money that supports the Institute is highly leveraged with other funds provided by stakeholders, universities, and researchers. In order to address key problems in the best way possible, research project proposals are evaluated by peer-review and approved by our Research Advisory Board composed of members from the U.S.G.S. Water Science Center, State Environmental Agencies, academia, and industry. During the FY13 period, the Maine Institute supported four (4) research projects, including two student-directed projects: (1) Analytical method development of trace PPCP's in surface waters; (2) Informatics methods to model mercury in aquatic systems; (3) Assessing effects of changing climate on drinking water; and (4) Using lake water temperatures as a signal of climate. The Institute supported additional Information Transfer activities such as working with municipalities to manage salt to protect water quality, the Maine Water Conference and groundwater education in rural communities (GET WET!) activities. These projects directly provided support to three graduate students and involved several undergraduate students in a variety of roles.

The Maine Institute Director, John Peckenham, also serves as the Associate Director of the Senator George J. Mitchell Center for Environmental and Watershed Research. The Mitchell Center provides the administrative home for the Water Resources Research Institute. This structural association greatly enhances our efforts to have the Maine Institute increase the breadth and accessibility of water research in Maine. The Mitchell Center is the recipient of a five-year EPSCoR grant from the National Science Foundation to develop the Sustainability Solutions Initiative. This grant is fostering even greater multi-institutional interdisciplinary research, including several projects related to water resources.

The 19th annual Maine Water Conference was held in March 2013 and continues to be the most important regional event for the water community. The conference attracted more than 300 registrants. The number of people and organizations who support and contribute to this conference reflects the importance of water to the people of the State of Maine. Through the hard work of Institute staff, the Conference Steering Committee, and other key supporters, we have been able to address the important water issues in Maine and to bring together diverse interest groups.

The Water Resources Research Institute's affiliation with the Mitchell Center gives us the ability to support both large and small projects that address important local needs. It also provides us leverage to develop and attract funding from other agencies. This program is strongly supported by our Vice-President for Research who has contributed $50,000 to the 104b research projects. In FY13, the Maine Institute had projects that brought in other funds and contributions from state agencies (e.g. Department of Inland Fish and Wildlife, Department of Environmental Protection), federal agencies (e.g. Fish and Wildlife, Environmental Protection Agency, National Oceanic and Atmospheric Agency), and foundations. None of these projects would be possible without the support of the federal Water Resources Research Institutes program and the U.S.

Geological Survey.

Research Program Introduction

Grants funded under Section 104b each deals with important aspects of Maine's highly valued water resources. The Maine Water Resources Research Institute supports research and information transfer projects using 104b funds. Projects are awarded on a competitive basis using a two-stage selection process. The Research Advisory Committee, comprised of the Institute Director, Regional U.S.G.S. Chief Scientist, State and Federal Agencies representatives, and Water Resources Professionals, set the research priorities based on current state needs and issues. The Institute issues a call for pre-proposals in the spring. The pre-proposals are reviewed by the Executive Committee (5 individuals) and full proposals are solicited for 150% of available funds. Full proposals are sent out for external review (out-of-state reviewers are required). The full Research Advisory Committee (12 members) reads the proposals and reviews to provide the Institute Director with a ranked selection of proposals to fund. Much effort is made to solicit suggestions for themes, to diversify the types of projects funded, and to include researchers from the small colleges and universities in the state. Preference is given to support new faculty and projects developed by students. Investigators are encouraged to collaborate with state and federal agencies and to seek additional contributions for their projects.

Informatics approaches for reuse and modeling of heterogeneous mercury data

Basic Information

Title:	Informatics approaches for reuse and modeling of heterogeneous mercury data
Project Number:	2012ME260B
Start Date:	3/1/2012
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	Maine 2nd
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Models, Toxic Substances
Descriptors:	None
Principal Investigators:	Kate Beard, Linda Bacon, Melinda Neville

Publications

1. Beard, K. and Neville, M. 2014. An Event and Place-Based Context Model for Environmental Monitoring (submitted).
2. Neville, M. and K. Beard. 2014. Old Data and New Technologies- Integrating legacy research for modeling future outcomes. Maine Water and Sustainability Conference. Augusta, ME.
3. Neville, M. and K. Beard. 2013. Biogeochemical Informatics for Reuse and Modeling of Legacy Mercury Data. 11th International Conference on Mercury as a Global Pollutant, Edinburgh, United Kingdom.

WRRI FY2013 Project Report

Informatics approaches for reuse and modeling of heterogeneous mercury data

Project duration: September 1, 2012 to February 28, 2014

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Abstract

The project funds supported a PhD student for the development of a database that synthesized two decades of coastal Maine mercury (Hg) research across many different sample media. In this stage of the project, the Mercury Research Ontology was developed to facilitate comparison of the disparate datasets in a computer readable language. Ontologies foster data integration and reuse for geospatial modeling and prediction of Hg dynamics. The Hg ontology will support several key activities and goals, including an information 'blueprint' to support data collection and reporting with the use of common terms and controlled vocabularies, identifying data gaps, results of specific regulations, and potential areas of concern that warrant further data collection and analysis to inform decision making.

Problem and Research Objectives

With more differences than similarities among legacy mercury (Hg) research data, how do we begin to collate, collaborate and build a better Hg research network? Environmental monitoring projects use many data sources and types, but often lack the cyberinformatics infrastructure to preserve the knowledge from all available data. Knowledge of spatial and temporal contextual differences among environmental observations can be crucial to interpretation and analyses, as well as facilitating sharing and reuse of data beyond the original collection context.

Increasingly, information systems play a more active role in scientific data management. The profusion and complexity of data in many disciplines is approaching a size where databases alone are insufficient tools. The scope of this proposed work is to maintain, expand, and utilize the existing database of

Maine’s legacy Hg research, use the database to develop the basic ontological design and evaluate its competency, and then to validate the ontology approach with regional scientists working on Hg-related research. Our research objectives were to:

* Develop an ontology-based information system for Hg biogeochemistry and legacy research data integration.

* Evaluate and validate the competency of the ontology design with other researchers.

* Share with stakeholders to stimulate collaboration, information dissemination, and data integration.

Methodology

We continue to assess data quality and consistency and updating the established Hg database with current available data. The ontology development used OWL (Web Ontology Language) and the Protégé Ontology editor. The OBOE Extensible Observation Ontology has been developed for scientific observations, but lacks specific spatial or temporal context needed to fully describe biogeochemical data. Our research expands OBOE with entities and relationships specific to Maine’s legacy Hg research, incorporating observations, relationships, events, and instances relevant to understanding the fate and transport of Hg in a temperate ecosystem.

Explicitly linking the relationships between environmental observations and their larger contextual setting (such as the spatial and temporal relationship to meteorological events), has several benefits but presented a number of challenges. First, the spatial extent of a rain storm and the spatial position of the precipitation monitoring station may not fall on or near the site of an environmental observation, nor does a rain storm need to occur during sampling to have an effect.

The OBOE ontology recognizes the importance of context by including a hasContext relationship but does not specifically identify spatial, temporal, and process based context information. This work built on OBOE and borrowed concepts from other existing ontologies. OBOE provided the ontology concepts of Observation, Characteristic and Measurement. The Geospatial Event Model (GEM), gives us SpatialSetting and TemporalSetting relationships, and we borrow the classification of Biome from the Environment Ontology. Using OWL (Web Ontology Language) we can specify domain – property – range relationships to build our ontology.

Two ontologies have been developed in this project. The first is directly related to Hg fate and transport in the environment- essentially the formal specification of the sources and sinks present in the Hg cycle. The second ontology describes, catalogs and links the research data, between projects as well as each datum location within the Hg cycle ontology.

Principle Findings and Significance

The complexity of Hg biogeochemistry in temperate ecosystems has proven to be a challenging data management puzzle. But, by incorporating higher level ontologies that have established spatiotemporal data relationships we have begun to link our data together in a novel, searchable and reasonable model.

We will be demonstrating our ontological model's efficacy in interpreting disparate datasets in the coming months. When debugged and comprehensive (for available Maine data), the Hg Ontology will be a tool available to the research community online, therefor providing context for future as well as past research on Hg pollution in Maine.

Next Steps

Collaboration with data producers is essential to fully describe the spatial, temporal, climatic, and landscape contexts appropriate for each dataset. We have many pieces of the "puzzle" in place and can start to test the competency of the ontologies. This proofing stage, in which we query the system to ensure consistency in definitions and categorizations, continues to evolve with additional data sources and types. Following the completion of this phase, we will be hosting a workshop with other local Hg researchers to further test and expand the ontologies.

Optimized Pre-Treatment for Fluorescence Monitoring of Surface Fresh Water Contamination

Basic Information

Title:	Optimized Pre-Treatment for Fluorescence Monitoring of Surface Fresh Water Contamination
Project Number:	2013ME293B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	2nd
Research Category:	Water Quality
Focus Category:	Methods, Models, Water Quality
Descriptors:	None
Principal Investigators:	Howard Patterson, John Cory Ahern, Gregory Hall

Publications

There are no publications.

Progress Report:
Project title: Optimized Pre-Treatment for Fluorescence Monitoring of Surface Fresh Water Contamination.

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Note: This is not a final report. The start of this project was delayed until Sept. 1st 2013 so the 12 month timeframe for experiments ends August 31st 2014. A final report will be filed after this 12 month span has been completed. A no-cost extension was filed to allow funds to continue to be used until 2/28/15.

I. Problem and Research Objectives:

A. *Problem:*

Disasters like the Deepwater Horizon oil spill and the cost of its cleanup have served as a hard lesson for public and private research centers as well as the petroleum industry to develop new response technologies to prevent impact to the environment. Such large spills are infrequent but thousands of smaller spills occur every year. Nearly 20,000 oil spills are reported to the EPA annually.[1–4] Most of these spills are from overfilled fuel tanks and overturned tanker trucks, some of which enter fresh water sources including one in Maine during March 2011 when a tanker overturned and spilled over 1000 gallons of diesel into the Pleasant River endangering a local salmon hatchery.[5,6] Phenol is just one of the many toxic compounds in refined fuels.[7,8] A rapid means of quantification of phenol and other petroleum contaminants is necessary.

A wide variety of personal care product and pharmaceutical (PPCP) contaminants are being detected in natural water sources around the world. There is a growing body of scientific literature demonstrating the extent of the problem; from antidepressant pharmaceuticals being found in fish tissue to anticonvulsants in our drinking water.[9,10] The synthetic estrogen 17α ethinyl estradiol (EE2) is now ubiquitous in waterways and has been found to negatively affect fish reproduction.[11] Estrogen mimics similar to EE2 have been linked with decreased fertility rates and increased incidence of reproductive organ cancer in humans and wildlife.[12]

EPA water detection methods, mainly gas chromatography-mass spectrometry (GC/MS) and liquid chromatography-mass spectrometry (LC/MS) can detect small concentrations but involve a great deal of time and resources as well as produce relevant amounts of hazardous waste. There will always be a market for the traditional highly accurate methods of trace contamination but for most purposes a novel, cost effective and more sustainable method is needed. Current methodology for identifying pollutants in natural water supplies is costly and can take several weeks to generate full results. In comparison, luminescence spectroscopy combined with PARAFAC statistical analysis is rapid and less expensive in both personnel time and equipment. The potential time and cost benefit of the proposed method will allow for more frequent sampling and allow for the assessment of a wider range of potential contaminants to provide a more accurate analysis of water quality. The ability to quickly and cost-effectively quantify contaminants of concern in water supplies has far reaching implications from public health in the third world to national security. The Patterson group among others have had success in discriminating pollutants in environmental samples around the ppm level using excitation emission (EEM) followed by PARAFAC analysis.[13–15] The goal of this research is to develop a screening process for quantifying water borne pollutants using luminescence/PAFAFAC analysis. This effort fits well with the Maine WRRI initiative of protecting fresh water supplies.

C. Research Objectives:

-Develop screening methods for single pharmaceuticals/PPCPs including EE2, estriol, mestranol, sulfamethoxazole and ibuprofen as well as the petrochemical phenol. These studies are to be conducted in a variety of water types including deionized water, deionozed water spiked with dissolved organic carbon as well as natural river water.
-Adapt the methods to allow for discrimination of compounds in complex mixtures of similar substances. Natural waters contain mixtures of closely related chemicals so it is essential to be able to discriminate between them.
-Compare limits of detection(LOD) for screening method to those published by the EPA using GCxMS/LCxMS.
-Provide a cost benefit ratio of the limited pretreatment plus EEM/PARAFAC analysis to the full pretreatment and GC/MS EPA method.

II. Methodology:

A. Sampling:

The research started with selecting water sources. Deionized (DI) water was used as the medium to start with because it would provide the cleanest spectra. Next solutions of DI were spiked with 10ppm(10mg/L) of either standardized fulvic, humic or Suwannee River composite DOC. These solutions mimic a natural system while being able to control the variety and amount of interfering components. Finally, Stillwater River water was collected in Orono Maine and tested as a medium. Phenol is dissolved directly into the natural water solution. Similarly, less water soluble petrochemicals could be brought into solution using the method developed by Stelmaszewski et al. (2011) for no.2 oil.[16] EE2 and the other pharmaceuticals were dissolved in the collected water at environmentally relevant concentrations. Solution pH was monitored for any changes after the compounds were added.

B. Pre-treatment:

EPA pre-treatment methods were carried out in their entirety including solid phase extraction and liquid/liquid extraction on spiked samples with environmentally relevant concentrations of the pharmaceuticals and phenol contaminants in river water to test for detection limits using GCxMS. (EPA method 8270D for phenol and method 1698 for EE2.) Solvent phase extractions were also evaluated as a means to decrease the LOD for our fluorescence/PARAFAC based screening methods. The objective our developing new fluorescence based methods is to limit the need for such costly and environmentally hazardous methods.

C. Detection and Modeling

Fluorescence spectroscopy was used to determine the identity and concentration of compounds in solution. Fluorescence spectroscopy is an efficient method of analyzing samples because it requires very time and has needs only limited sample preparation. The resultant emission wavelength can be highly indicative of certain groups of compounds and relative intensity among samples can help gauge concentration.[14] The researchers used a Jobin Yvon Horiba Fluorolog fluorometer with accompanying Fluorescence software. The PARAFAC analysis was done on John Ahern's and Jim Killarney's licenses of Matlab-based PLS toolbox from Eigenvector Inc.

One-dimensional fluorescence was taken for each sample via a process called synchronous scan fluorescence spectroscopy. (SSFS) Simple excitation or emission scans hold either the emission or excitation wavelength constant as collect signal for the other variable. Synchronous scan works in a different fashion where the excitation and emissions are collected simultaneously. This is possible by setting a constant difference between the collected excitation and collected emission. This difference is referred to as $\Delta\lambda$. Given a delta lambda of 25nm and a spectral range of 300-500nm the excitation scan runs from 300-500nm and simultaneously the emission scan is collected from 325nm-525nm. The rate of the simultaneous scans is kept constant so the emission scan is always observing at a wavelength 25nm higher than the excitation scan so there is no problem with scattering. This method is very rapid however it requires the time and expertise to differentiate excitation signals from emission signals and the ideal $\Delta\lambda$ can be difficult to find for complex solutions.

Two-dimensional fluorescence of each sample were taken by scanning the excitation wavelength and recording the emission wavelength and intensity at each excitation. This data is commonly referred to as an excitation emission matrix(EEM) and it provides a three-way data set of excitation, emission and intensity. The EEM is still considered bilinear because intensity is a dependent variable. Due to their bilinear nature, fluorescence EEMs can be analyzed using PARAFAC analysis and other multi-way chemometric methods.[17]

EEMs were taken by passing light from a xenon lamp through a cuvette of sample and detecting the fluorescence reading. In EEM spectroscopy excitations are run at given increments (1-5 nm) and the emission spectra are collected for each. Once the given excitation range has been run the computer composes a matrix of excitation vs. emission vs. intensity in photon counts per second. 3-D spectra can be rendered from this with excitation on the y axis, emission on the x and intensity on the z axis. See an example in figure 1 below of EE2 spectra the group collected. Alternatively a color-coded 2-D image can be made with intensity being indicated by the color providing contours much like those in a topographic map.

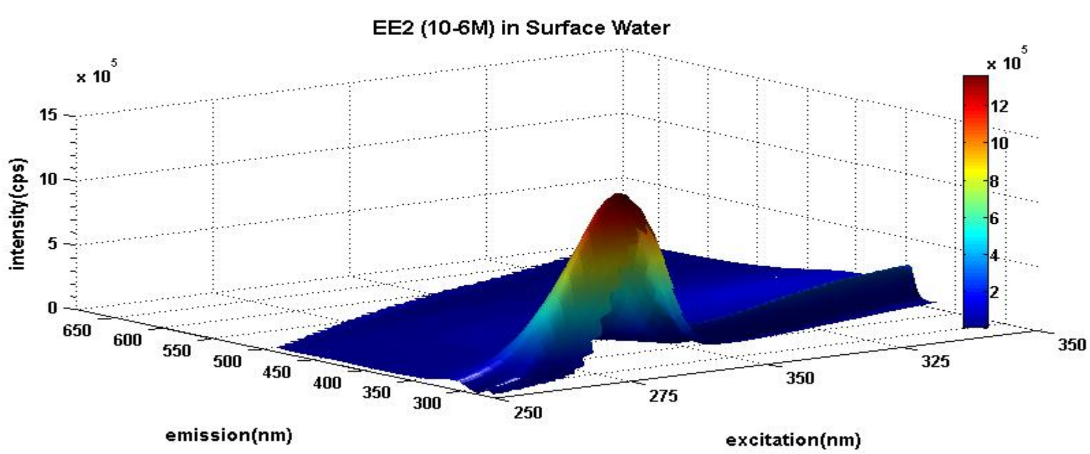

Figure 1: EEM spectra collected of 17α-ethinylestradiol spiked in natural water samples at $4.6x10^{-6}$M (1.4mg/L)concentration.

These spectra are helpful in qualitative judgments but cannot be used directly to make quantitative analyses nor can their matrices without the proper software. The problem is especially severe because natural water samples have so many types of compounds in them that have overlapping characteristic signals (in this case excitation/emission wavelengths). The same problem arises for other characterization techniques like overlapping retention times and fragmentation patterns in GCMS data. PARAFAC analysis can process the matrices allowing for separation of signal overlap and account for energy transfer processes like quenching.[14]

PARAFAC analysis is used to help deconvolve spectral data so that specific compounds can be measured in matrix. The primary advantage of using PARAFAC for the proposed work is not having to measure the standard spectra of every contributor to fluorescence within the spectra in order to determine the contributions of all the factors. This consideration is particularly useful when analyzing samples of complex mixtures where standard solutions of the components are unavailable. PARAFAC is able to take advantage of the bilinear nature of EEM spectroscopy. This advantage allows the researchers to utilize EEM spectroscopy where fluorescence emission spectra are taken at many different excitation wavelengths so signals from multiple different compounds can be observed. PARAFAC studies have been published by the Co-PI: Gregory Hall for compounds in oil.[18],[19] Both of these methods could be coupled with more conventional analysis of chromatographic data by Principal Components analysis, and therefore show the correlation between spectral and chromatographic results.[20] While chromatographic techniques exist that can address these issues, they can be cost and time prohibitive; therefore, a spectral validation of the pollutant levels in water is needed. This is extremely important in rural sites where responders may not arrive before the pollution impacts the waterway. The software proposed herein performs all the above methods.

GC-MS and LC/MS are the industry standards for the pollutants in question. No other technique is as reliable for trace analysis. GC-MS spectra were collected on a Hewlett-Packard 5890 Gas Chromatograph with a Hewlett Packard MSD 5970 as a detector. A 30mx.25mm ID DB-5 MS column was used. EPA method 8270D is useful for a wide range of semi volatile organics including the petrochemicals since the pollutants selected are usually found in a blend of other semi volatiles like diesel fuel. This method has detection limits of 10μg/L(10ppb) for Phenol. EPA method 1698 covers a broad range of steroids and personal care products and was used for EE2 to give a detection limit of 2ng/L (2ppt). The same method will be used for other pharmaceuticals including estriol, mestranol, sulfamethoxazole and ibuprofen.

III. Principal Findings and Significance:

A. Detection Limits:

Synchronous Scan Fluorescence Spectroscopy (SSFS) Limits of Detection: Limits of detection were determined for EE2, IBU and SUL in de-ionized water and three different dissolved organic matter (DOM) types, Suwanee humic acid, Suwanee fulvic acid and a Stillwater River sample. In de-ionized water, EE2 has a limit of detection(LOD) of roughly 10^{-9} M (296ng/L/296ppt).

The quantum yield of fluorescent compounds (photons emitted/incident photons) as well as spectral overlap of signals both have a strong impact on the limit of detection. DOM can interfere with the ability to discriminate the EE2 signal in luminescence spectra. This is because of fluorescence quenching between EE2 and DOM as well as an overlap of the luminescence signals between the two species. Figure 2 shows varying concentrations of EE2 in a 10 ppm fulvic acid solution. The fulvic acid peak is broad and shows a maximum at roughly 400 nm. It is an unresolved peak that runs from 300 nm to 500 nm. The water Raman scattering peak is also very visible at around 300 nm. In a fulvic acid aqueous solution, the EE2 peak is clearly visible at 10^{-6} M (296µg/L/296ppb) concentration because of its high quantum yield, EE2 ($\phi = 0.067$)[127]. However, it is inseparable from the water scattering peak and tail of the fulvic acid peak at a concentration of 10^{-7} M. (29.6ppb)

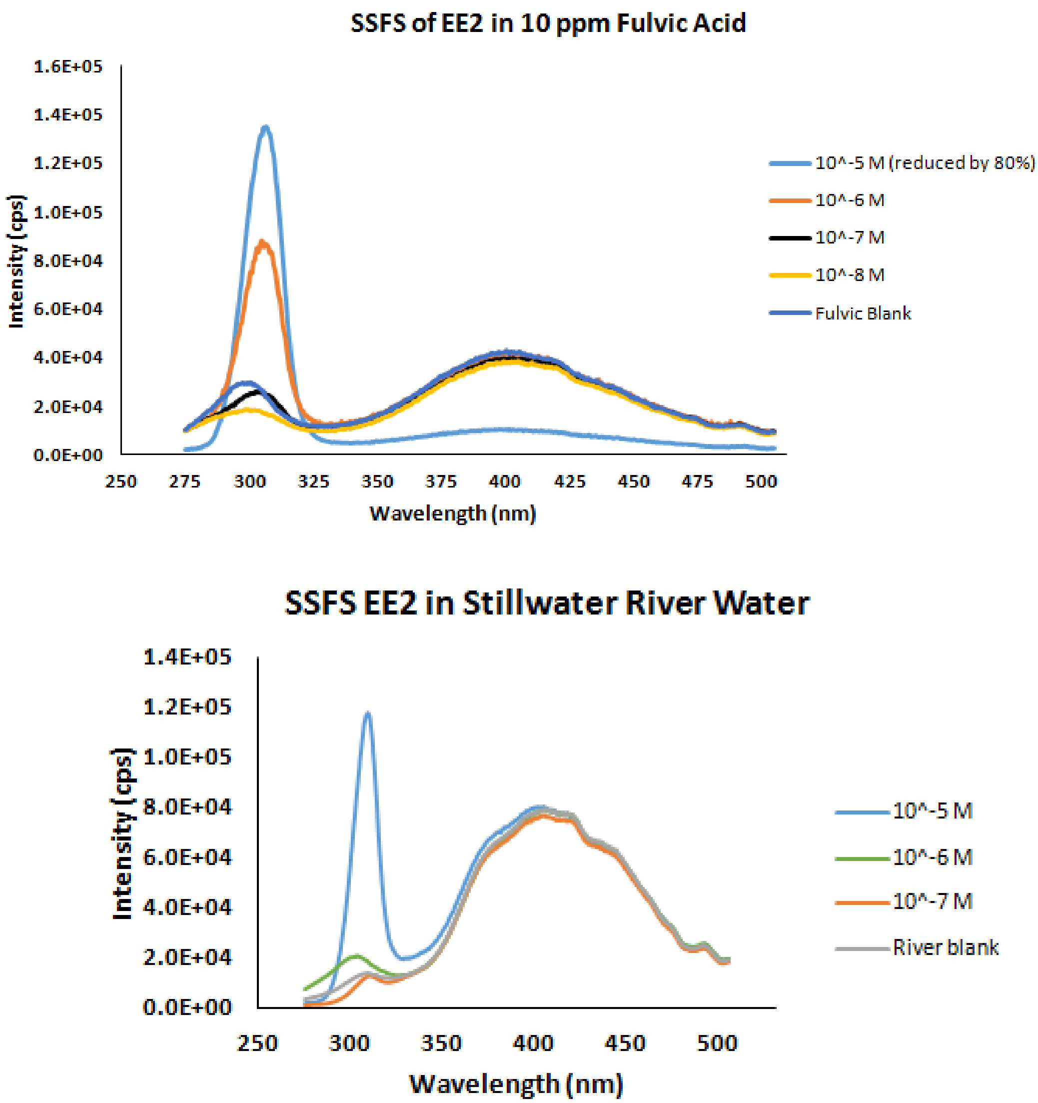

Figure 2: SSFS of EE2 at varying concentrations (Δλ = 29 nm, emission wavelength) in Fulvic acid DOM and Stillwater River samples.

Just like with fulvic acid, the LOD for EE2 is significantly higher when in both humic acid and Stillwater River samples compared to de-ionized water. The LOD for samples spiked with humic acid had similar LODs to those with fulvic but was marginally lower for the Stillwater River sample.

Ibuprofen has a much lower quantum yield than EE2 at similar concentrations (ϕ = 0.056)[128] . This makes detection using SSFS more difficult. However, its peak is further from both the DOM background. Its LOD is between 10^{-7} and 10^{-8} M in de-ionized water. Its peak is well separated from DOM so there is not as much loss of LOD when compared to EE2 as peak overlap is much less. The LOD for IBU in all three DOM type samples was roughly 10^{-6} M. Because of its wavelength distance from the DOM source, IBU experienced a 10 fold increase in its LOD. A 100 fold increase in LOD was observed for EE2 when DOM was added because it is significantly closer to the DOM peaks. Additionally, EE2 is a slightly more hydrophobic compound than IBU (K_{ow} EE2 = 4.15, K_{ow} IBU = 2.48) so more quenching of the hydrophobic fractions of the DOM occurs.

Sulfamethoxazole is a compound that shows strong fluorescence; however, its synchronous scan emission maximum is at a higher wavelength than the other two PPCPs studied and thus more overlap with the DOM peak is expected. In de-ionized water, emission signal was observed above background at a 10^{-8} M concentration level. When spiked in DOM samples, the LOD was lessened to 10^{-6} M concentrations levels.

EEM/PARAFAC Limits of Detection: PARAFAC models based on EEM data were created to detect EE2 in de-ionized water, fulvic acid and Stillwater River solutions. The LOD for EE2 in de-ionized water using PARAFAC treated EEM data was found to be between 10^{-9} and 10^{-10} M. Figure 3 displays the relationship between the PARAFAC score value and the known concentrations. The score value refers to the value the PARAFAC model assigns to a single of group of fluorescent factors. This value is designed to be proportional with the concentration of a single compound (as it is in this case) or a group of similar compounds for more complex solution analysis. The strong, linear relationship between the model assigned "score" and known concentration means that the model is an accurate predictor of concentration within the range studied.
This prediction curve is used to predict unknown concentrations loaded into the model.

Models for the fulvic acid and Stillwater River samples were constructed in the same fashion as the deionized water. The model is able to predict concentrations between 10^{-8} and 10^{-9} M in these water types. It is no surprise that the LOD is lower for the DI sample versus the DOM spiked samples since there are no other substances in DI to interfere with the EE2. The DOM profile of Maine rivers is mostly fulvic acid so it is expected that the results for the river water are very similar to the fulvic spiked samples[130]. A significant improvement in the LOD for EE2 (10^{-8} and 10^{-9} M) was observed when using PARAFAC modeling for detection compared to the SSFS alone method(10^{-6} to 10^{-7} M). EE2 emission wavelength overlaps the edge of the DOM signal and is difficult to measure at low EE2 concentrations. The ability of the PARAFAC to resolve overlapping signals greatly improved the limits of detection for EE2.

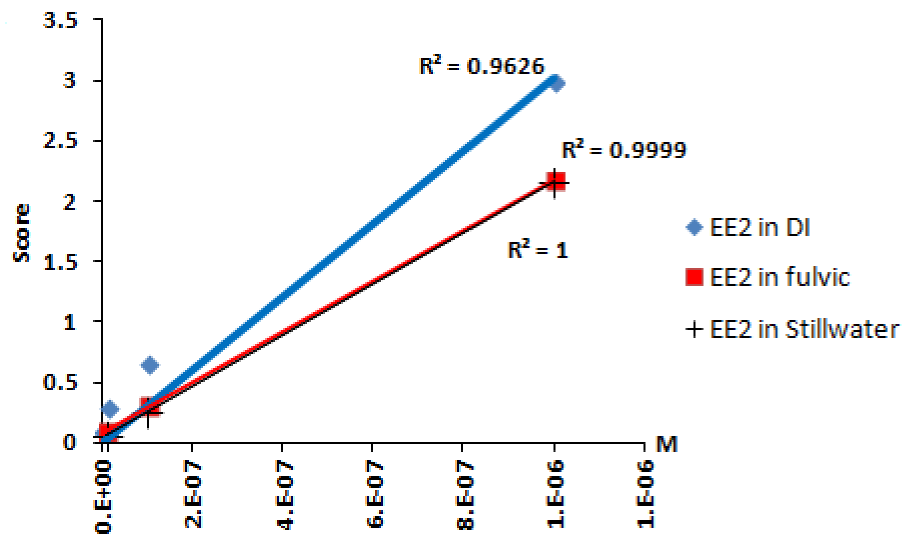

Figure 3 Beer's law plot for the ability of the model to predict sample concentration of EE2 in de-ionized, fulvic acid and Stillwater River aqueous samples.

Using the same modeling technique for ibuprofen detection, a LOD between 10^{-6} and 10^{-7} M was determined for both the fulvic acid and Stillwater River samples (figure 4). These were the same range of detection of the SSFS method so there was no added benefit of using the more involved PARAFAC procedure instead of SSFS. This is because the IBU peak is already so separated from the DOM signal.

Using the modeling technique for sulfamethoxazole detection, a LOD between 10^{-8} and 10^{-9} M was determined for both the fulvic acid and Stillwater River samples (figure 5). PARAFAC proved to be a useful tool as the LOD range was increased by a factor of ten when compared to SSFS methods. Sulfamethoxazole displays strong luminescence, however, it has considerably more overlap with DOM luminescence than the other compounds tested. There was a improved LOD with sulfamethoxazole demonstrating the usefulness of PARAFAC to resolve overlapping spectra in EEMs.

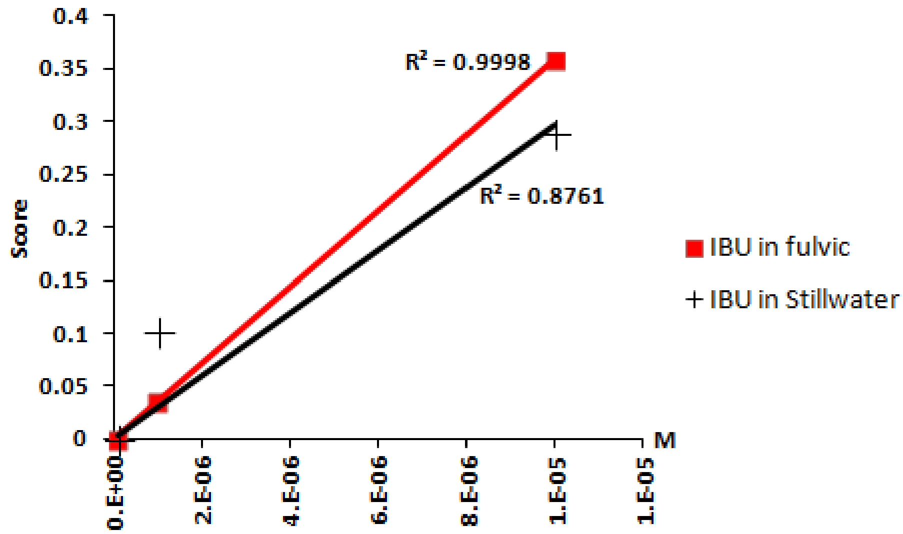

Figure 4: PARAFAC score versus sample concentration for a model of ibuprofen in fulvic acid and Stillwater River aqueous samples.

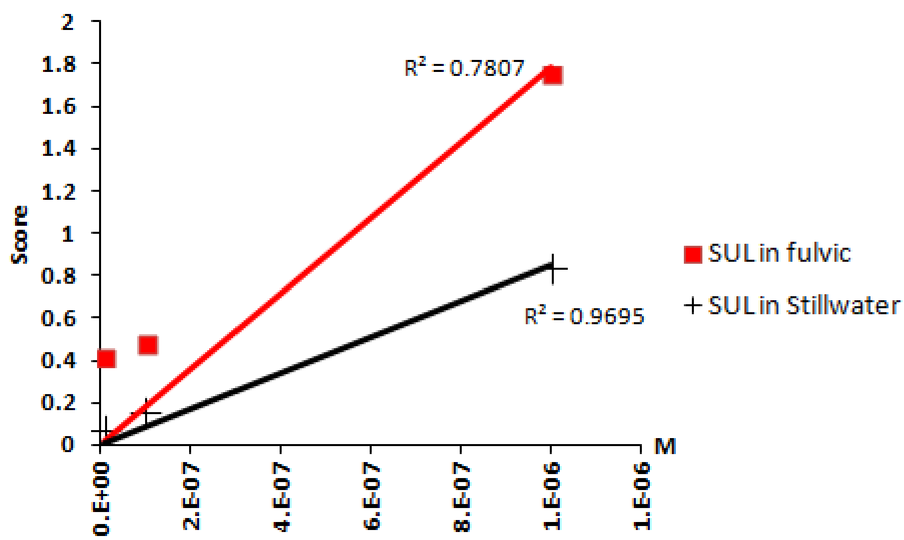

Figure 5: PARAFAC score sample concentration for a model of Sulfamethoxazole in fulvic acid and Stillwater River aqueous samples.

Chemical Extraction Prior to PARAFAC: Four different concentrations of EE2 (10^{-7}, 10^{-8}, 10^{-9}, 10^{-10} M) were extracted using $MeCl_2$, put through a roto-evaporator and then re-concentrated in MeOH. EEMs were taken from the extracted organic solution and modeled with PARAFAC. This procedure provides an LOD for EE2 somewhere between a 10^{-9} and 10^{-10} M concentration. Improved modeling and perhaps a larger concentration step could improve this result. Nevertheless, these results are encouraging since the limits of detection of this simple procedure are approaching the detection limits for GC-MS based methods.

Table 1 summarizes the maximum detection limits in for the three different fluorescence procedures discussed. SSFS provides a limit of detection of 10^{-6} to 10^{-7} M for all three PPCPs in natural water samples. This level of detection would be appropriate for highly polluted sources or for methods where up-front separation, such as HPLC, is performed beforehand as LOD values for EE2 and SUL were considerably better in neat samples. Collecting EEMs of the samples and analyzing them with PARAFAC showed marked improvement for EE2 and SUL. Both of these compounds show strong luminescence and benefit from the spectral clarity that PARAFAC provides. When EE2 was extracted into a non-polar solvent and concentrated, the limit of detection was further improved. This method was easy to perform and was not costly from a material perspective. The limits of detection were comparable to more commonly used and more expensive methods.

Table 1 Comparison of limits of detection for 17α-Ethinylestradiol (EE2), ibuprofen (IBU) and sulfamethoxazole (SUL).

	PPCP (M)		
	EE2	IBU	SUL
Synchronous Scan	10^{-6}-10^{-7}	10^{-6}-10^{-7}	10^{-6}-10^{-7}
EEM/PARAFAC	10^{-8}-10^{-9}	10^{-6}-10^{-7}	10^{-8}-10^{-9}
Extraction/Concentration PARAFAC	10^{-9}-10^{-10}		

Table 2 summarizes the observed LODs for EE2 in each of the tested media via luminescence spectroscopy alone, luminescence with the aid of PARAFAC analysis and finally, extraction prior to luminescence and PARAFAC treatment after it.

Table 2: Limits of Detection for EE2 with just SSFS, w/ PARAFAC analysis, and w/ Extractions plus PARAFAC analysis.

Sample	**LOD for SSFS/EEM alone**	**w/ PARAFAC**	**w/ PARAFAC & extraction**
De-ionized water(DI)	10^{-9}-10^{-10}M	10^{-9}-10^{-10}M	10^{-10}-10^{-11}M
DI w/ fulvic acid	10^{-6}-10^{-7}M	10^{-8}-10^{-9}M	
DI w/ humic acid	10^{-6}-10^{-7}M	10^{-8}-10^{-9}M	
Stillwater River	10^{-6}-10^{-7}M	10^{-8}-10^{-9}M	10^{-8}-10^{-9}M

B. Ongoing Studies:

Detection Limit for Mestranol:

Mestranol has been dissolved in a variety of media including DI water, methanol, 50:50 mixtures of water and methanol as well as chloroform. In each case the optimal excitation is 285nm and the optimal emission is 297.5. This narrow Δλ makes it difficult to pick out the compound in a spectra especially in complex solutions. Synchronous scan as well as EEM spectroscopy have been tried. The detection limit in the clean solvents (no DOC or other pharmaceuticals present) is roughly 5^{-4}M. Efforts to better discriminate mestranol are still ongoing.

Analysis of Mixtures of EE2, IBU and SUL:

The ability to discriminate individual pharmaceuticals from a mixture dissolved in water was tested. Deionized water as well as Suwanee River standard DOC doped DI water were used. The PARAFAC analysis of these studies is still ongoing. Results will be included in the next report.

Limits of Detection of Phenol:

Synchronous scan as well as EEM alone was able to detect phenol in deionized water down to 4.3^{-7}M. EEM with PARAFAC were able to discern phenol in deionized water down to 1^{-7}M. This is the same limit of detection as the much more costly, time consuming and environmentally hazardous GC-MS method. Using fulvic, humic or Stillwater River water raised the LOD to 6.0^{-7}M for untreated and 2.0^{-7}M for PARAFAC treated samples. The PARAFAC analysis offered little benefit to the LOD because the phenol emission is at high enough energy(λ_{em}: 295nm) and has a high enough quantum yield to be well separated from the DOM peaks as seen in figure 6.(the DOM peaks cannot even be seen) These numbers are very close to the 1.1^{-7}M LOD for GCxMS. Considering the low LOD for the luminescence method it seems to be the obvious choice for detection of phenol. However, studies are still ongoing on mixing the phenol with similar petrochemicals. Many other compounds have a great deal of spectral overlap with phenol[21] and may have much higher quantum yields. It is expected that the LOD will be much improved using PARAFAC treatment of luminescence data for phenol detection in such solutions. Results on these studies will be included in the next report.

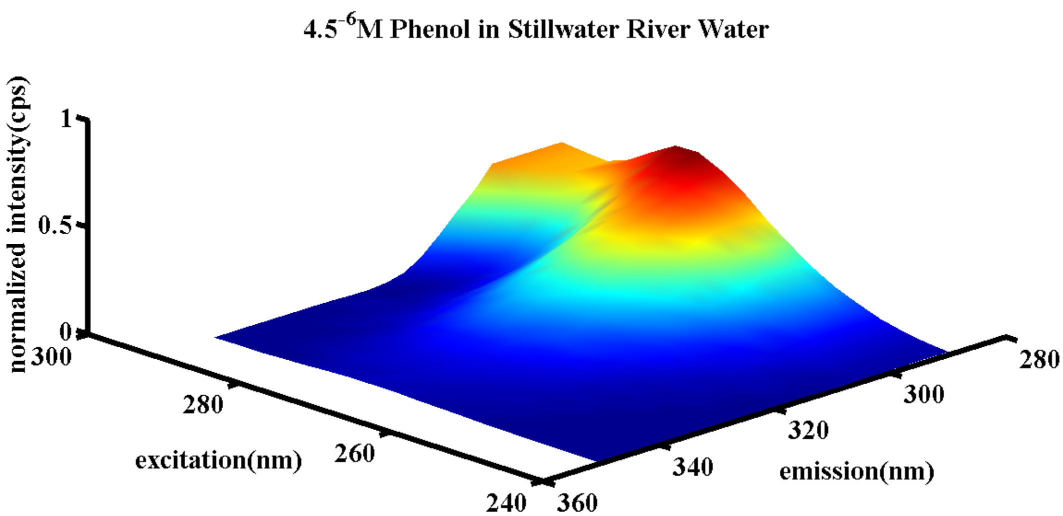

Figure 6: EEM spectra for 4.5^{-6}M Phenol in Stillwater River water demonstrating the ease of seeing phenol even in natural waters.

***C. Cost Analysis*:**

Obtaining GC/MS data via EPA Method #1698 takes approximately 4 hours including pre-treatment. The cost of the solvents, surrogate and fortifying solutions is about $40. As previously stated the detection limit is 1-10ppb for natural waters.

The PARAFAC analyzed EEM data took about 20 minutes to obtain and did not require any solvent or other solution expenses.

The capital costs of the EPA method are higher than the fluorescence setup and PARAFAC software especially when you factor in maintenance costs of the GC-MS as seen in the table below.

Table 3: Cost comparison between methods.

Category	Cost for GC/MS method	Cost for EEM/PARAFAC method
Instrument and software	**$60,000**	**$55,000**
Maintenance	$500+	0
Consumable supplies	$500+	0

C. Summary

Fluorescence Spectroscopy is an effective and low cost tool for detecting contaminants in natural water systems. We reached limits of detection comparable to those reached by more expensive detection methods. PARAFAC analysis aided in the detection process especially when the studying mixtures of different target compounds in solution. We were able to distinguish between the target compounds and other components naturally found in water like DOM. Lastly, doing liquid-liquid extractions prior to fluorescence further lowered limits of detection.

Supplemental Details:

A. Student Support and Training:

The gains of the proposed work go beyond publications. An essential part of this work is to give students the training necessary to become water resource professionals. The graduate student John Ahern and the two undergraduates Monique Theriault and Nina Caputo all participated in conducting the research. John and fellow group member Dr. James Killarney trained and oversaw the undergraduates in the use of the instruments and gave them the background information necessary to conduct the research. John is grateful to be supported with a stipend for his role in the research. John intends to submit papers to journals with the findings.

B. Achievements:

-John Ahern presented at the Maine Water Conference in Augusta in April.

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Assessing threats of changing climate to drinking water quality

Basic Information

Title:	Assessing threats of changing climate to drinking water quality
Project Number:	2013ME294B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	Second
Research Category:	Water Quality
Focus Category:	Acid Deposition, Climatological Processes, Water Quality
Descriptors:	None
Principal Investigators:	Jasmine Saros, Sarah Nelson

Publications

1. Brown, R.E., Saros, J.E., Nelson, S.J. 2014. Algal community response to increases in dissolved organic carbon over recent decades. Joint Aquatic Sciences Meeting. Portland, Oregon.
2. Brown, R.E., Saros, J.E., Nelson, S.J. 2014. Algal community response to increases in dissolved organic carbon over recent decades. Maine Water and Sustainability Conference. Augusta, Maine.
3. Brown, R.E., Saros, J.E., Nelson, S.J. 2013. Algal community response to increases in dissolved organic carbon in Maine lakes: implications for drinking water utilities. 22nd North American Diatom Symposium. Bar Harbor, Maine.

Assessing threats of changing climate to drinking water quality

Project Number: 2013ME294B

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Assistant Research Professor, University of Maine

Problem and Research Objectives

Many lakes in New England are currently clean enough to be exempt from expensive filtration processes required by federal legislation. Across Maine, there are more than 40 surface freshwater sources used for drinking water; 10 of these are not filtered as part of the treatment process and collectively serve several hundred thousand people. At present, however, there is little information available to inform adaptation strategies as physical (e.g., temperature) and chemical (e.g., acid deposition) climate change occurs. Such strategies range from altering the strength of various purification processes to implementing expensive filtration infrastructure if a tipping point in water quality is crossed.

Due to a combination of reduced sulfur (S) emissions as well as increasing air temperatures and changing hydrology, widespread changes in dissolved organic carbon (DOC) are occurring across lakes situated in northern forests, including those of New England. In the northeastern US, data from US EPA long-term research and monitoring (LTM) projects have been used to evaluate trends in the biogeochemical response of lakes to reduced S deposition in a changing chemical climate.

While trends in DOC concentrations have been documented, the implications of these changes for the physical and biological structure of lakes in New England remain unclear. DOC is one of the most important regulators of lake ecosystems, owing to its strong influence on vertical habitat gradients via light attenuation and mixing depths. It also affects phytoplankton community structure by providing additional carbon sources (either directly or indirectly via stimulation of heterotrophic bacterial growth) for mixotrophic algae, including chrysophyte algae. In northern, low productivity lakes, blooms of certain species of colonial chrysophytes are a concern for drinking water utilities, as these algae can cause taste and odor problems that are typically described as fishy or vegetable-like.

Whereas there is evidence to suggest that algal changes may occur with changes in water transparency and lake mixing depths, the extent to which these changes are occurring across Maine's lake ecosystems remains unclear, but has important implications for management of drinking water sources.

The goal of this project was to determine whether changing concentrations of DOC are affecting the physical and biological structure of lakes, and thereby threatening drinking water quality.

<u>Methodology</u>

Paleolimnological methods were used to investigate whether these physical and biological changes have occurred in three sets of lakes: 1) three of the 16 Long-Term Monitoring (LTM) lakes of Maine (for which 30 years of biogeochemical data are available through EPA-funded projects) that have experienced significant increases in DOC since 1985; 2) three LTM lakes that have not experienced any change in DOC since 1985; 3) Floods Pond, the sole drinking water source for the city of Bangor. Select lake characteristics are provided in Table 1. LTM lakes were selected in pairs, such that lake pairs as similar as possible in area, maximum depth, and current DOC concentration but with or without significant changes in DOC over the past 24 years are partnered here.

Table 1. The six Long-Term Monitoring Lakes plus drinking water source for Bangor (Floods Pond) selected for this study, with lake area, maximum depth, and current concentrations of dissolved organic carbon (DOC) provided. Lakes with an asterisk are those with significant increases in dissolved organic carbon since 1985. Shading indicates lake pairs (Tilden & Little Long, Salmon & Bracey, and Second & Jellison) for comparison in the study. NA = not available.

Lake	Lake area (ha)	Max depth (m)	DOC (mg L^{-1})
Bracey*	8	9	5
Salmon	4	10	3
Little Long*	24	25	3
Tilden	15	11	3
Second	27	17	5
Jelison*	18	12	5
Floods	257	44	NA, but low color

While the bathymetry of Floods Pond is quite different from the rest of the lakes used in this study, the LTM lakes are used here because DOC concentrations have been routinely and consistently documented in these systems in recent decades, revealing increasing DOC in some LTM lakes whereas no changes in DOC occurred in others. We included Floods Pond because it is the sole drinking water source for Bangor, and the paleolimnological study allows us to investigate whether physical and biological changes have occurred in this system in recent decades.

An Aquatic Research Instruments gravity corer was used to collect sediment cores from the deepest part of each lake. Sediments were dated from ^{210}Pb activities counted by gamma ray spectroscopy methods in the UMaine Physics Department. Chronology was based on the constant rate of supply (CRS) model. Diatom assemblages were determined in each sub-sample of the cores with an Olympus BX-51 differential interference contrast microscope at 600 or 1000x. Diatom assemblages were used to reconstruct lake thermal structure, using the recent model developed by Saros et al. (2012).

Principal Findings and Significance

Lake sediment chronology

The radiometric profiles showed an exponential decline in ^{210}Pb activities in all seven cores, suggesting minimal sediment mixing. Age models were established with an average error in ^{210}Pb dates ranging from ±6 to ±10 years for the last century. ^{210}Pb chronologies were extrapolated back to 1850 assuming constant sedimentation rates.

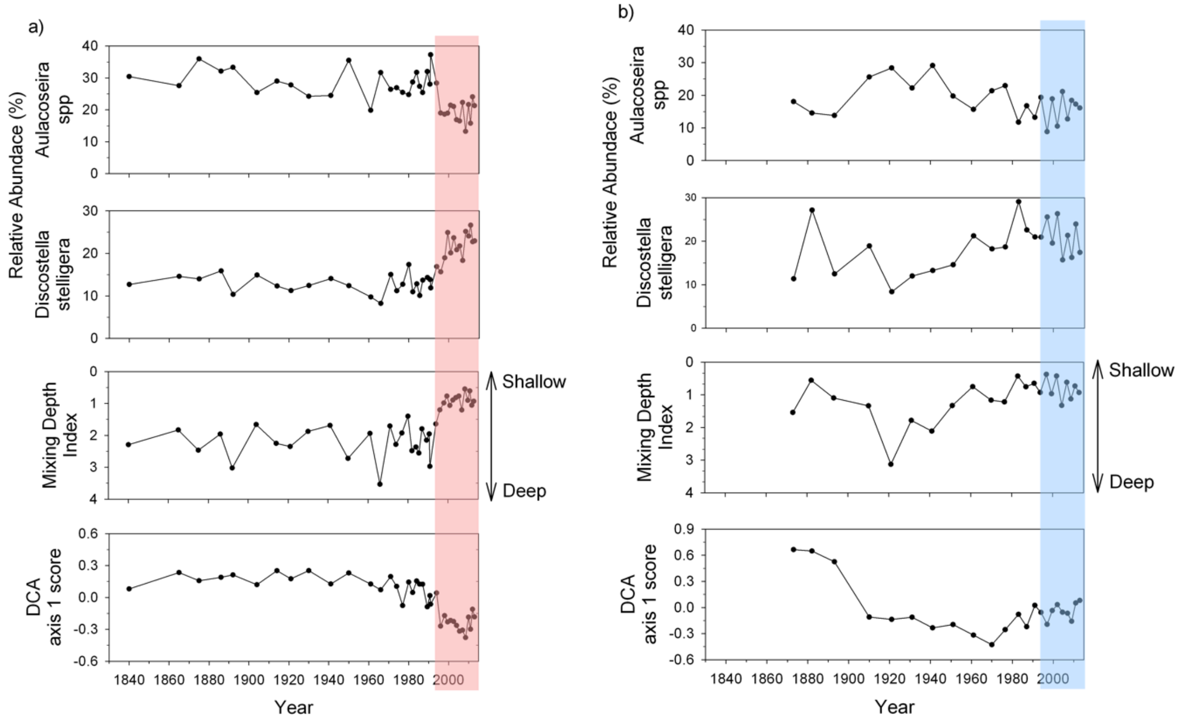


Figure 1. Diatom stratigraphy, Mixing Depth Index, and detrended correspondence analysis (DCA) axis 1 score for all taxa > 1% relative abundance for; (a) Bracey Pond; and (b) Salmon Pond. Red shading indicates period of increased DOC concentration in Bracey Pond. Blue shading indicates period of decreased DOC concentration in Salmon Pond.

Bracey and Salmon pair

Bracey Pond has experienced a significant ($p < 0.05$, $n = 58$) increase in DOC concentration from 4.4 mg/L in 1993 to 6.4 mg/L in 2013. There was little turnover in the diatom community structure of Bracey Pond from mid 1800's until the early 1990's, when there was a large change in the diatom assemblage. During this time there was a sharp decrease in *Aulacoseira* species from ~30% relative abundance to ~20% coinciding with an increase in *Discostella stelligera* (from ~15 to 25%). This shift leads to a decrease in inferred lake mixing depth since the 1990's (Figure 1a).

Salmon Pond has experiences a significant ($p < 0.05$, $n = 61$) decrease in DOC concentration from 1993 to 2013, currently at 3.1 mg/L. There was a large change in diatom community structure in Salmon Pond around the turn of the 1900's; however there has been little diatom turnover since the early 1990's. The relative abundances of both *Aulacoseira* species and *Discostella stelligera* have remained stable around 15 and 20% relative abundance respectively. This leads to no change in the inferred mixing depth since the early 1990's (Figure 1b).

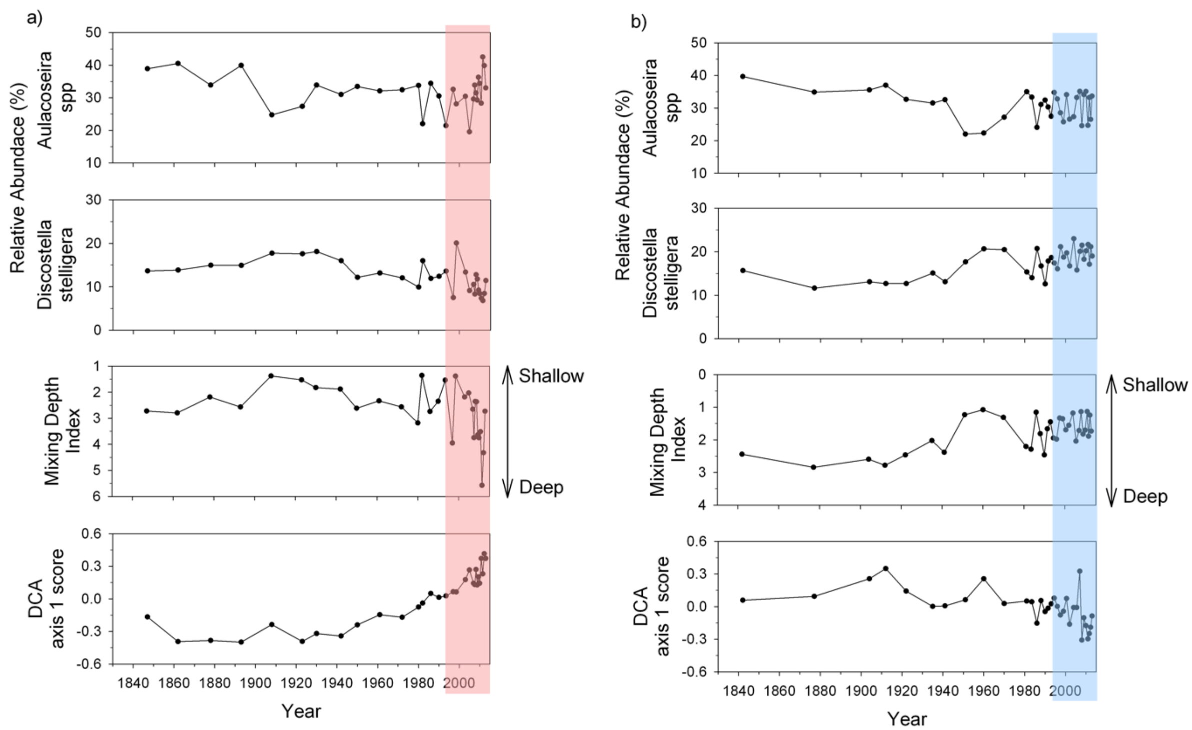


Figure 2. Diatom stratigraphy, Mixing Depth Index, and detrended correspondence analysis (DCA) axis 1 score for all taxa > 1% relative abundance; (a) Little Long Pond; and (b) Tilden Pond. Red shading indicates period of increased DOC concentration in Little Long Pond. Blue shading indicates the same time period in Tilden Pond with no change in DOC.

Little Long and Tilden pair

Little Long Pond has experienced a significant increase in DOC concentration from 1.5 mg/L in 1993 to 2.4 mg/L in 2013. There was little turnover in the diatom community structure in Little Long Pond from the mid 1800's until the 1940's, when there has been a gradual change in the diatom assemblage until present. During the mid 2000's, there was an increase in *Aulacoseira* species from ~30% relative abundance to ~40% coinciding with a decrease in the relative abundance of *Discostella stelligera* (from ~15 to 10%). This change leads to an increase in inferred mixing depth since the mid 200's (Figure 2a).

Tilden Pond had a DOC concentration of 3.3 mg/L in 2013 and has experienced no significant change since 1993. There was a slight change in diatom community structure in Tilden Pond around the 1910's, 1960's, and in the late 2000's. The relative abundances of both *Aulacoseira* species and *Discostella stelligera* have remained stable around 30 and 20% relative abundance respectively. This leads to no change in the inferred mixing depth since the early 1990's (Figure 2b).

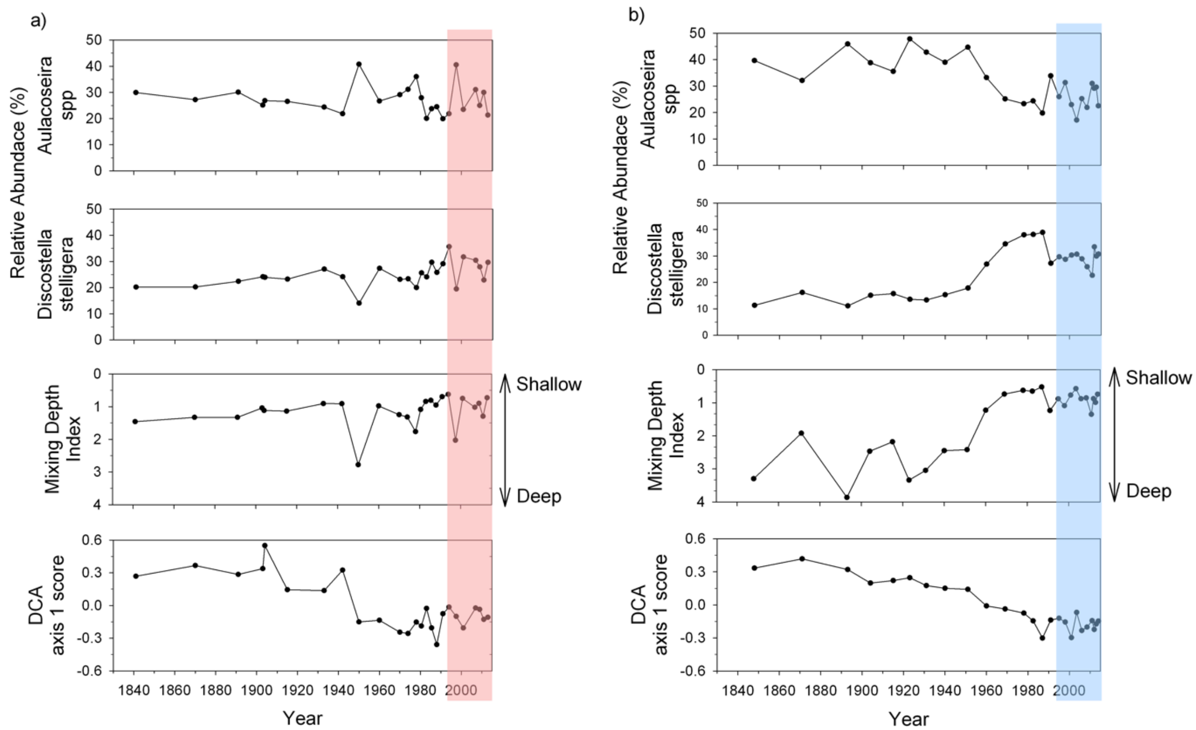


Figure 3. Diatom stratigraphy, Mixing Depth Index, and detrended correspondence analysis (DCA) axis 1 score for all taxa > 1% relative abundance; (a) Jellison Pond; and (b) Second Pond. Red shading indicates period of increased DOC concentration in Little Long Pond. Blue shading indicates the same time period in Tilden Pond with no change in DOC.

Jellison and Second pair

Jellison Pond has experienced a significant ($p < 0.05$, $n = 56$) increase in DOC concentration from 3.9 mg/L in 1993 to 5.4 mg/L in 2013. There was a slight change in diatom community structure around the 1910's and again in the 1940s, the latter associated with a peak in *Aulacoseira* species. There is another peak in *Aulacoseira* species to about 40% relative abundance occurring in the late 1990's coinciding with a decrease in *Discostella stelligera* to 20% relative abundance. However, both *Aulacoseira* species and *Discostella stelligera* remain stable around 25 and 30% respectively from the early 2000's to present. This leads to an increase in inferred mixing depth for a brief period of time in the late 1990's and a return to stable inferred mixing depths in the 2000's (Figure 3a)

Second Pond had a DOC concentration of 5.0 mg/L in 2013 and has experienced no significant change since 1993. There has been a gradual change in the diatom assemblage since the mid 1800's until the early 1990's, however there has been little turnover since. There was a decrease in the relative abundance of *Aulacoseira* species from ~45 to 20% from the early 1950's to the early 1980's coinciding with an increase in *Discostella stelligera* (from 20 to 40%). However, the relative abundances of both *Aulacoseira* species and *Discostella stelligera* have remained stable around 25 and 30% relative abundance respectively since the early 1990's. This leads to no change in the inferred mixing depth since the early 1990's (Figure 3b).

Significance

The shift from heavily silicified *Aulacoseira* species to smaller *Discostella stelligera* in Bracey Pond corresponds with the recent increases in DOC concentration and consistent with a decrease in lake mixing depth. The lack of this shift in Little Long might suggest the diatom response may vary depending on the DOC concentration. Although Little Long has experienced an increase in DOC the last couple decades, the concentration is still relatively low. Little Long was the clearest of the study lakes with a Secchi disk of 8.8 m and had the deepest mixing depth at 4 m in 2013. Since the relationship between DOC and light attenuation is exponential, the effect of the increase in Little Long may have had less of an effect on the light and temperature structure than the increase in Bracey. The lack of diatom change since the early 1990's in the lakes experiencing either no change or a decrease in DOC suggests that the recent DOC changes are altering the ecology of these lakes.

We are still in the process of analyzing the core from Floods Pond, and should have those results during the summer of 2014.

Partnership for Monitoring Maine Lake Temperatures in a changing Climate, Short-term Variability and Long-term Trends.

Basic Information

Title:	Partnership for Monitoring Maine Lake Temperatures in a changing Climate, Short-term Variability and Long-term Trends.
Project Number:	2013ME295B
Start Date:	5/15/2013
End Date:	5/14/2014
Funding Source:	104B
Congressional District:	second Maine
Research Category:	Climate and Hydrologic Processes
Focus Category:	Conservation, Ecology, Education
Descriptors:	None
Principal Investigators:	Daniel Buckley, Scott Williams

Publications

There are no publications.

Maine Water Resources Research Grants Program Summary Report

Partnership for Monitoring Maine Lake Temperatures in a changing Climate, Short Term Variability and Long Term Trends.

Dan Buckley, Chair, Division of Natural Sciences, University of Maine Farmington
Buckley@Maine.edu, phone 207-778-8151
Scott Williams, Executive Director, Volunteer Lake Monitoring Program

Problem and Research Objectives:

Temperature records over the last five decades have indicated that global temperatures have risen approximately 1^0F during that time and recently investigators have shown the impact that this is having upon attributes of aquatic environments such as ice cover and flow regimes of streams (Huntington et al, 2003) onset of ice cover and ice out (Hodgkins et al. 2005) and the epilimnetic temperatures of some of our largest lakes(Austin and Coleman, 2008). Lake water temperature data in Maine historically has been collected during water quality monitoring activities on a weekly or bi-monthly basis and as such are not very useful in examining long term trends. One exception to this is the data on water temperatures from the Lake Auburn intake pipe which are between 1 and 2^o C higher most months of the year than they were 50 years ago (data from Lewiston Auburn Water District). Recent lake temperature studies have dealt with a single lake or a few lakes at a time. Lake response to climatic changes (Heat budgets, mixing regime, thermal profiles, epilimnetic temperatures) may be mitigated by regional or local climate, lake size (surface area, maximum and average depth), elevation and geography. Maine with its many lakes and active volunteer monitoring program along with the development of inexpensive reliable water temperature monitors for season-long deployment presents a unique opportunity to monitor and analyze the effects of climate change on lake temperatures and thermal regimes in lakes with different physical dimensions and location attributes over time. This data collected annually will provide information on seasonal stratification and lake mixing regimes now and in the future. The importance of this long-term study cannot be overstated as we attempt to understand how the changing climate will impact nutrient cycles and lake productivity, dissolved oxygen concentrations, fisheries habitat, and ultimately biodiversity and aquatic species distributions.

Project Objectives:

- Increase the number of monitored lakes (currently between 25 and 30) in an ongoing long-term study where temperatures being logged every 15 fifteen minutes seasonally to between 40 to 50 lakes.
- Use the data in the analysis of long term trends and correlates with inter-lake variation among the lakes being studied.

- Use the data from specific lakes to examine daily fluctuations in temperature profiles and lake response to short term climatic changes.
- Provide this information to the Maine Volunteer Lake Monitoring Program and the Maine Department of Environmental Protection for dissemination to the public as appropriate and for the elucidation of emerging threats to water quality and lake ecology in Maine as lake temperatures change.
-

Methods: In a research program that began in 2007 seasonal water temperatures and light intensities in lakes are being monitored and logged every fifteen minutes by Hobo pendant data-loggers deployed at know locations in the spring by the UMF aquatic research team or our cooperating volunteers. Every temperature datum is time stamped and the all loggers are set to the same time regimen. The loggers are recovered in the fall and the data are downloaded and used in the calculation of average daily temperatures and elucidation of daily minimum and maximum temperatures. In most cases, a single data logger is placed in a lake at a depth of two meters, however in some lakes there are multiple loggers. In the latter cases the loggers may be buoyed in different parts of the lake at the same depth to look at horizontal location effects or multiple loggers are part of string designed to provide a record of changing vertical temperature profiles.

The WRRI grant allowed for the purchase of 49 additional Hobo loggers which have been used to add eight lakes to the study to date. In four of the lakes, Lake Auburn, Loon Lake, Round Pond and Middle Sandy River Pond, temperature profile strings with multiple loggers were deployed. In Lake Auburn the string was deployed last June and retrieved in November. In the other lakes the strings were deployed in the fall for retrieval this spring. In the other three lakes; Highland, Kezar, Pleasant, and Square Pond one or more loggers were deployed at 2m depth within 60 meters of shore. This past fall the summer’s data is downloaded and stored along data from previous years and currently the data loggers are being readied for this year’s deployment.

Principal Findings and Significance: While data has not been collected long enough to determine the impact of long term climate trends upon Maine lakes, the nuanced data provided by the loggers is very useful in elucidating lake temperature variability at depth, seasonal changes in temperature profiles and the near term impact of local weather upon lake temperatures and water movements. Figure 1 shows the 2013 summer profile for Lake Auburn. The figure shows the daily temperature variation by depth and that the variation appears to be the greatest between six and nine meters in depth. Given the diminished light intensity at these depths this variation appears to be the result of internal water movements, which is further backed up by the deviation of water temperature fluctuations from the solar signal as observed in Figure 2.

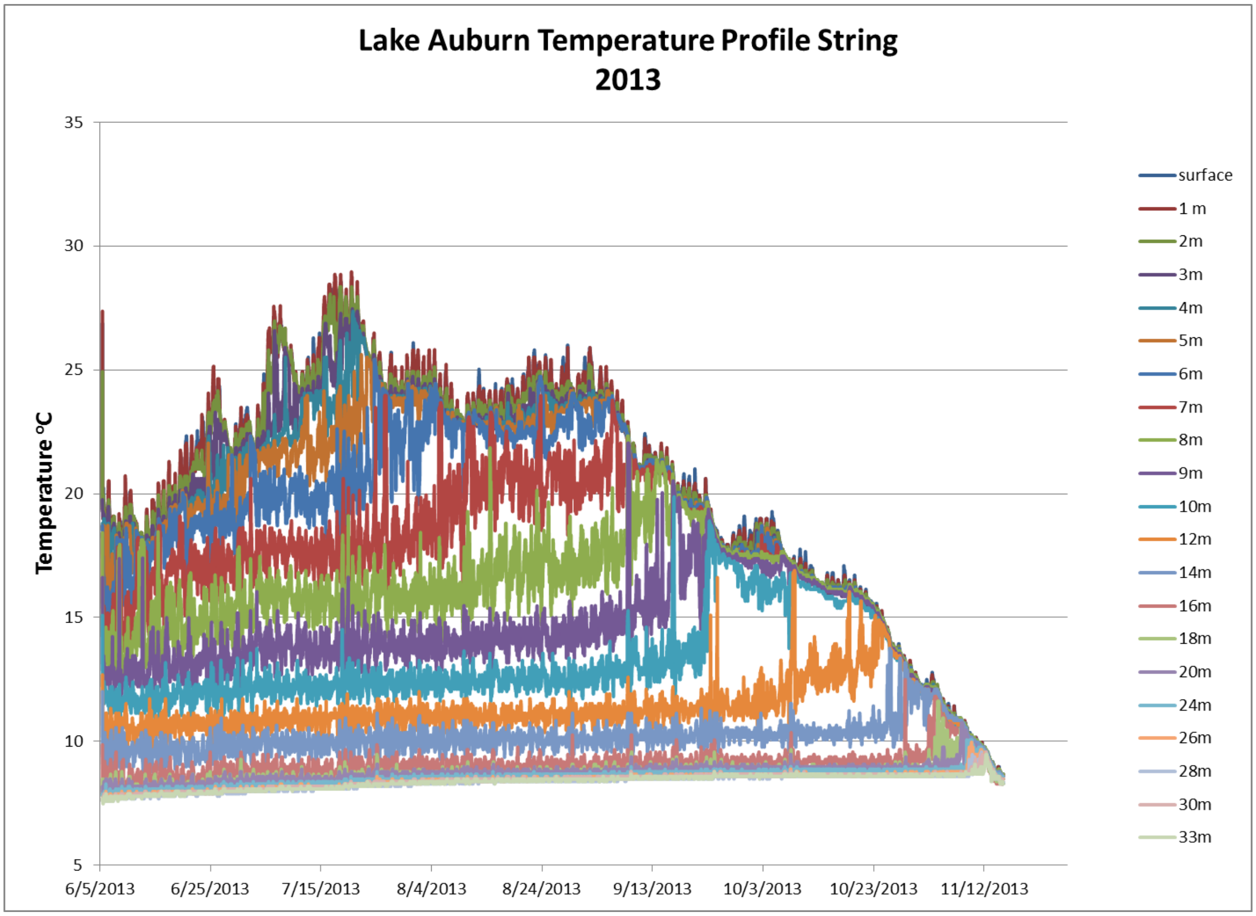


Figure1. Summer and fall water temperatures by depth for Lake Auburn, Maine.

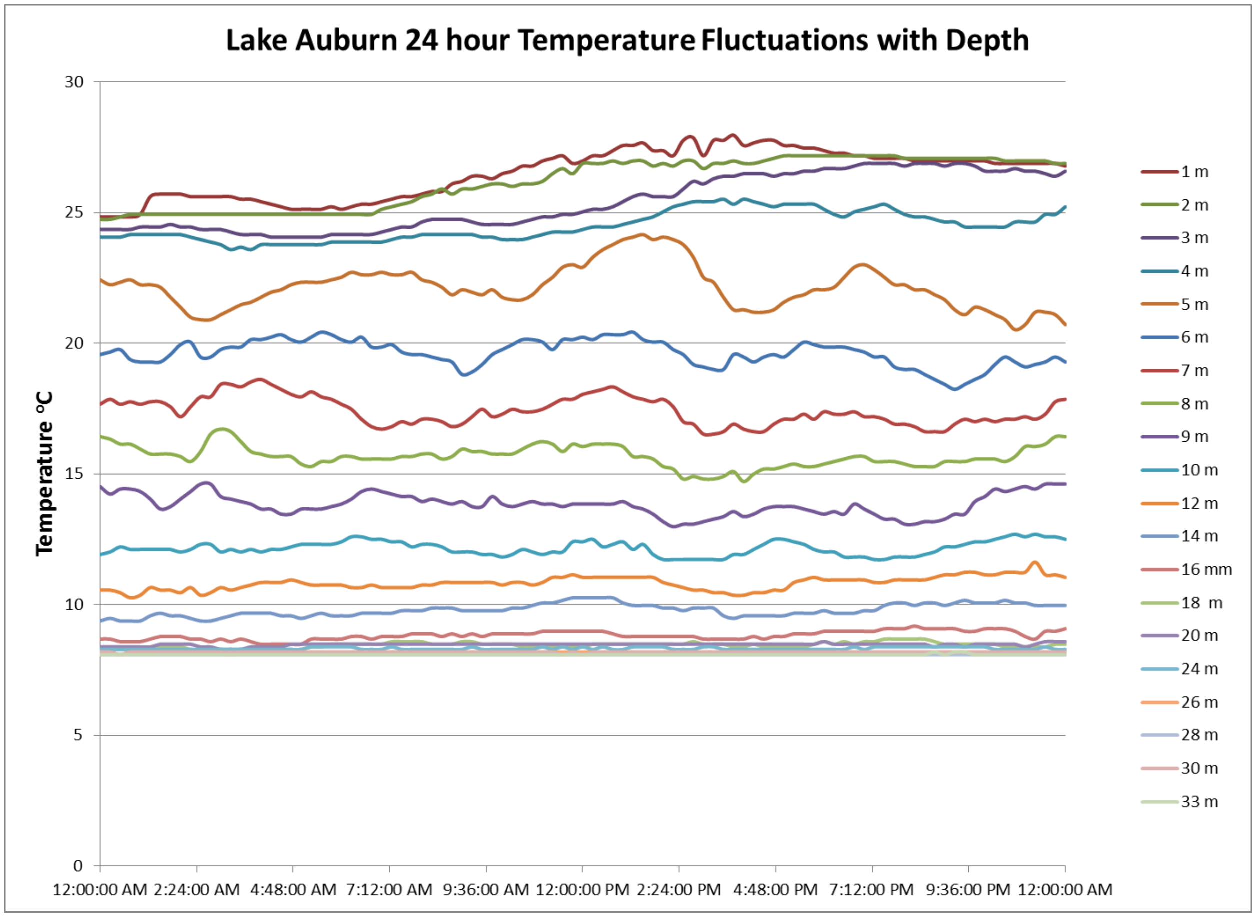


Figure 2. Lake Auburn temperature fluctuations by depth over a 24 hour period.

In Figure 3, The logger data from two different sites in Wilson Lake, Maine illustrates the effects of wind direction and water entrainment on water temperatures in medium sized lakes. At both sites the loggers are suspended at a two meter depth below the surface and the buoys are separated by about 2 km distance. The outlet to the lake is in the southeast corner of the lake with the major tributaries occurring on the Northwest shore. In general in Wilson lake water gains heat as it flows from northwest to southeast as shown by the data, however when the wind blows out of the south in some afternoons the entrainment of warmer surface water at the north end of the lake causes an upwelling of cooler waters at the south end of the lake and a reversal of the typical temperature differences between the two sites. This type of water movement is important in distributing heat in the water column as well as exchanging it with the sediments.

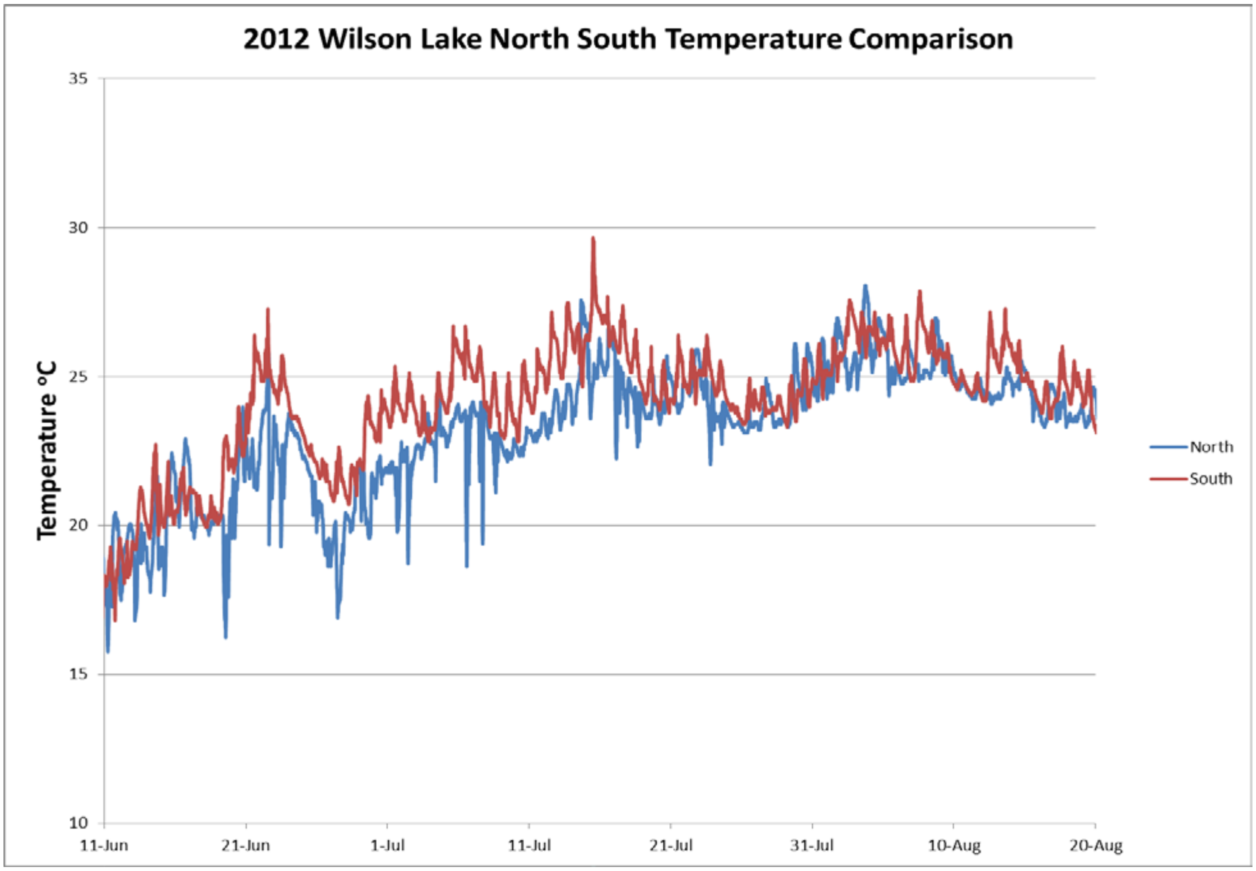
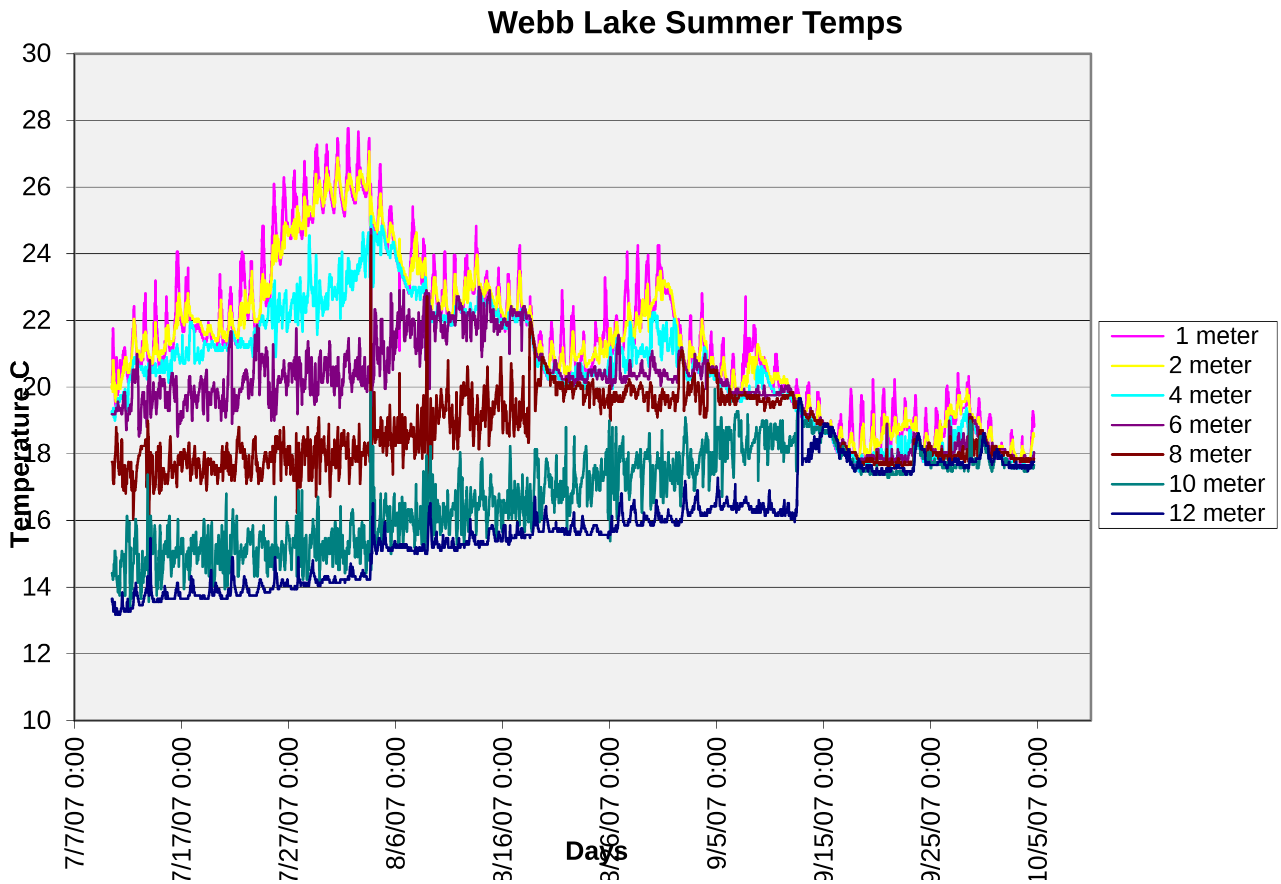


Figure 3. Wilson Lake temperature data recorded every 15 minutes.

In some cases local weather events and subsequent water movements are sufficiently strong to partially disrupt the thermal stratification and result in a sudden increase in bottom temperatures (Figure 4) as shown by the data from Webb Lake and a re-oxygenation of the hypolimnion as noted by the data from their VLMP volunteers.



Finally, continued use of Hobo loggers in monitoring lakes for the foreseeable future will provide a record of the long term effects of climate upon Maine's lakes thermal patterns and how such changes may impact other aspects of lake ecology.

Austin, J.A. and S. Coleman, A century of Temperature Variability in Lake Superior. Limnology and Oceanography, November 2008.

Hodgkins, G. A., I. C. James II, and T. G. Huntington. 2005 Historical Changes in Lake Ice-Out Dates as indicators of Climate Change in New England, 1850-2000. USGS Fact Sheet FS 2005-3002, January 2005

Huntington, T. G., G. A. Hodgkins, and R. W. Dudley 2003, Historical trend in river ice thickness and coherence in hydroclimatological trends in Maine. Climate Change 61: 217-236

Information Transfer Program Introduction

Information Transfer activities for the Maine Institute are an important part of our mission. Information Transfer activities can be categorized as: (1) Hosting the Maine Water Conference; (2) Producing web-based water information; (3) Participation on state-wide boards and committees; (4) Leading educational outreach such as K-12 STEM projects (GET WET!); (5) Publishing newsletters (electronic versions); and (6) Providing direct responses to inquiries. In additional to the effort made directly by the Maine Institute, we require researchers funded through the 104b program to include information transfer in their projects. Required information transfer include presenting research results at the Maine Water Conference and production of a one-page project fact sheet written for a general audience. We also encourage researchers to link research outputs to direct stakeholder interactions and K-12 curricula.

The Maine Water Conference is the leading event in the state and brings together a very broad array of water-interest groups. This conference is very popular and continues to be the most important information transfer event for the Maine Institute. The Maine Institute's web page is the location to find information for current issues, activities, and publications. The web page is co-located with the Mitchell Center's and is updated on a regular basis to include project outputs such as publications and presentations. Also, it serves as a notice board for meetings, student opportunities, and calls-for-proposals.

The Water Institute Director serves on several state-wide and national boards and committees (e.g. Maine Water Utilities Association, New England Interstate Water Pollution Control Commission, Penobscot River and Bay Institute, American Water Works Association, National Institutes for Water Research). These activities provide opportunities to promote relevant institute-sponsored research and education. Also, it provides a process for the Maine Institute to collect information about the concerns and challenges of water resources in the state and region. This effort helps to keep the Maine Institute at the core of water resources in the state and region.

Finally, the Water Institute receives public inquiries on a regular basis. Typically, someone is hoping that outcomes from funded projects can help solve their water-related problem. Responding to these inquiries is important and we make every effort to help citizens in finding answers and solutions to their problems. Although most inquiries come from Maine, we have received requests from around the globe.

Maine Information Transfer

Basic Information

Title:	Maine Information Transfer
Project Number:	2013ME296B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	2
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	None
Principal Investigators:	John M. Peckenham

Publications

There are no publications.

Publications

Peer Reviewed Publications

Bell, K.P., L. Lindenfeld, A. Speers, M. Teisl, and J. Leahy. Creating Opportunities for Improving Lake-Focused Stakeholder Engagement: Knowledge-Action Systems, Pro-Environmental Behavior, and Sustainable Lake Management. *Lakes & Reservoirs: Research & Management* (2013).

Calhoun, A, R. Brooks, and M. Hunter. Building Vernal Pools, But Will the Right Species Come? *Restoration Ecology* (submitted).

Cline, B.B., and M.L. Hunter. Open-Canopy Vegetation and Dispersal in a Forest Amphibian: An Experimental Assessment of Permeability. *Journal of Applied Ecology* (submitted).

Cronan, C.S. Biogeochemistry of the Penobscot River Watershed, Maine, USA: Nutrient Export Patterns for Carbon, Nitrogen, and Phosphorus. *Environmental Monitoring and Assessment* (2012), 184: 4729-4288.

Groff, L. A., A.L. Pitt, R. F. Baldwin, A.J.K. Calhoun, and C. S. Loftin. Attaching Radio Transmitters to Anurans: A Comparison and Evaluation of a Novel Technique Used in Four Studies. *Journal of Wildlife Research*.

Hall, D., L. Silka, and L. Lindenfeld. Advancing Science: Linking Knowledge with Action in Maine's Sustainability Solutions Initiative. *Maine Policy Review*.

Hart, D. et al. Strengthening the Role of Universities in the Theory and Practice of Sustainability Science: Maine as a Model System. *Ecology and Society* (in review).

Hart, D., and K.P. Bell. Sustainability Science: A Call to Collaborative Action. *Agricultural and Resource Economics Review* (2013).

Hart, Biggs, Nikora and Flinders. Flow Effects on Periphyton Patches and Their Ecological Consequences in a New Zealand River. *Freshwater Biology* (2013).

Jansujwicz, J., A.J.K. Calhoun, J.E. Leahy, and R.J. Lilieholm. Using Framing Theory with Mixed Methods to Develop a Private Landowner Typology. *Society and Natural Resources* (2013).

Jansujwicz, J.S., and T.R. Johnson. Understanding and Informing Permitting Decisions for Tidal Energy Development Using an Adaptive Management Framework. *Estuaries and Coasts*.

Jansujwicz, J.S., A.J.K. Calhoun, and R. Lilieholm, "Using Citizen Science Education and Outreach to Engage Municipal Officials and Private Landowners in Vernal Pool Conservation," *Environmental Management* (2013).

Johnson, T., and G.B. Zydlewski. Research for the Sustainable Development of Tidal Power in Maine. *Maine Policy Review*, 21, no.1 (2012): 58-64.

Johnson, T.R., J. Jansjuwicz, and G. Zydlewski. Stakeholder Perspectives of Tidal Power Development in Maine. *Estuaries and Coasts* (manuscript in development).

Loftin, C.S., A.J.K. Calhoun, S. Nelson, A. Elskus, and K. Simon. Does Mercury Bioaccumulate in Wood Frogs Developing in Seasonal Woodland Pools in Maine, USA? *Northeastern Naturalist* 19 (2012):579-600.

Nelson, S.J., K.E. Webster, C.S. Loftin, K.C. Weathers, 2013. Shifts in controls on the temporal coherence of throughfall chemical flux in Acadia National Park, Maine, USA. Biogeochemistry 116(1-3): 147-160. DOI: 10.1007/s10533-013-9884-7.

Pavri, F., A. Springsteen, A. Dailey, and J.D. MacRae. Land Use and Socioeconomic Influences on a Vulnerable Freshwater Resource in Northern New England, United States. *Environment, Development and Sustainability* (2012).

Peckenham, J., and T. Ashtankar. A Management Decision-Support Tool for Source Water Protection. *Journal American Water Works Association* (2012).

Peckenham, J.M., D. Hart, S. Smith, S. Jain, and W. King. The Path to Sustainable Water Resources Solutions. *Maine Policy Review* 21 (2012): 46-57.

Peckenham, J.M. and T. Ashtankar, 2013 (in review). A Decision-Support Tool to Build Water Supply Capacity: Methodological Development. Journal New England Water Works Association.

Peckenham, J.M. and S. Peckenham, 2014 (in press). Assessment of Quality for Middle Level and High School Student-Generated Water Quality Data. Journal American Water Resources Association, JAWRA-13-0179-P.

Ryan, K.J., J. Zydlewski, and A.J.K. Calhoun. Using Passive Integrated Transponder (PIT) Systems for Terrestrial Detection of Blue-Spotted Salamanders In Situ. *Journal of Herpetology*.

Snell, M., K.P. Bell, and J. Leahy. Local Institutions and Lake Management. *Lakes & Reservoirs: Research and Management* (2013).

Strock, K., S. Nelson, J. Kahl, J. Saros, W. McDowell, 2014. Decadal trends reveal recent acceleration in the rate of recovery from acidification in the northeastern US. Environ. Sci. Technol. 48(9):4681-4689.

Thornton, T., and J. Leahy. Trust in Citizen Science Groundwater Research: A Case Study of the Groundwater Education Through Water Evaluation & Testing Program. *Journal of the American Water Resources Association* 48, no.5 (2012): 1032-1040.

Thornton, T., and J. Leahy. Changes in Social Capital and Networks: A Study of Community- Based Environmental Management Through a School-Centered Research Program. *Journal of Science Education & Technology* 21, no.1 (2012): 167-182.

Presentations

Bacon, L.B., A. Amirbahman, S.A. Norton, B.F. Mower. Why the difference? Environmental factors influencing fish tissue mercury concentrations in temperate lakes. Maine Water Conference 2013.

Barajas, M., T.V. Willis, K.A. Wilson, and B. Kulik. 2013. Smallmouth Bass Predation on River Herring in the Kennebec/Androscoggin River Systems. Maine Water Conference, Augusta, ME.

Barton, A., C. Bennett, D. Buckley, R. Butler, J. Daly, W. Harper, R. Kurtz, N. Perlson, and S. Rousseau. 2013. Sustainability Strategies in the Rangeley Lakes Region. Maine Water Conference. Augusta, ME.

Beyene, M. D. Brady, S. Jain, J. MacRae, D. Martin, F. Pavri, J. Peckenham, A.S. Reeve, S.M.C. Smith, and C. Straub. 2012. Safeguarding a Vulnerable Lake-Watershed System: The Sebago Lake Watershed. Maine EPSCoR Conference. Orono, ME.

Brown, R.E., Saros, J.E., Nelson, S.J. 2014. Algal community response to increases in dissolved organic carbon over recent decades. 22nd Annual Harold W. Borns Symposium. University of Maine, Maine.

Brown, R.E., Saros, J.E., Nelson, S.J. 2013. Algal community response to increases in dissolved organic carbon in Maine lakes: implications for drinking water utilities. 22nd Annual Harold W. Borns Symposium. University of Maine, Maine.

Colby-George, J., T. Waring, K. Bell, C. Colgan. 2012. Landowner Choices and Landscape Level Change: An Agent Based Model Designed to Engage the Public. Maine EPSCoR Conference, University of Maine, Orono, ME.

Goff, S. 2013. Evolving Sustainability: Can Group Selection Create Sustainable Socio-Ecological Systems? Maine EPSCoR Conference, University of Maine, Orono, ME.

Groff, Luke. 2013. Habitat Use by Pool-breeding Amphibians in Maine’s Montane Region. Northeast Partners in Amphibian and Reptile Conservation, Crawford Notch, NH.

Groff, L. 2013. Hibernaculum Selection by Wood Frogs (Lithobates sylvaticus) in Maine’s Montane Region. Northeast Natural History Conference, Springfield, MA.

Groff, L. 2012. Habitat Use by Pool-Breeding Amphibians in Maine’s Montane Region. Maine EPSCoR Conference, University of Maine, Orono, ME.

Hutchins, K., L.A. Lindenfeld, K.P. Bell, L. Silka, and J. Leahy. 2012. Linking Knowledge with Action Through Municipality-University Partnerships, Public Participation in Scientific Research, Portland, OR.

Kus, E., H. Aumann, N. Emanetoglu, B. Cline, and M. Hunter. 2012. Tracking Juvenile Amphibians with Harmonic RADAR. Maine EPSCoR Conference. Orono, ME.

Levesque, V., K.P. Bell, and A.J.K. Calhoun. 2013. Sustainability in Maine Municipalities. Maine Water Conference, Augusta, ME.

Levesque, Bell, and Calhoun. 2012. Municipal Vernal Pool Policy: Sustainability Science in Action. Maine EPSCoR Conference, University of Maine, Orono, ME.

Martin, D., A.S. Reeve, and S. Smith. 2013. Sebago Lake Stream Monitoring. Maine Water Conference. Augusta, ME.

Martin, D. 2012. Creating a Water Budget for Sebago Lake: Quantifying Surface Water Flow. Maine EPSCoR Conference, University of Maine, Orono, ME.

McGreavy, B., M. Miller, J. Disney, L. Lindenfeld, and L. Silka. 2012. Planning for Resilience: Integrating Citizen Perspectives in a Conservation Action Planning Process. Public Participation in Scientific Research Preconference, Ecological Society of America Annual Convention, Portland, OR.

McGreavy, B. E. Fox, J. Disney, M. Miller, L. Lindenfeld, L. Silka, and C. Petersen. 2013. A Collaborative Model for Conservation Action Planning: Group Communication and Partnership Development for Ecological and Economic Resilience in Frenchman Bay. Poster presentation at the Maine Water Conference, Augusta, ME.

McGreavy, B., L.A. Lindenfeld, L. Silka, K. Hutchins, H. Smith, and C. Budzinski. 2012. Participation in a Sustainability Science Project: Perspectives on Stakeholder Engagement, Partnerships, and Agency. Public Participation in Scientific Research Preconference, Ecological Society of America Annual Convention, Portland, OR.

Meyer, Johnson, Lilieholm, and Cronan. 2013. Identifying Opportunities for Watershed Protection and Regional Planning in a Mixed-Land Use Modeling Framework. Conference on Students as Catalysts for Large Landscape Conservation, Colby College, Waterville, ME.

Olsen, A.A., Bodkin, M., Baumeister, J.L., and Hausrath, E.M. 2013. Early serpentinite weathering reactions. Geological Society of America Northeastern Section Meeting, Bretton Woods, NH.

Negrich, K., Olsen, A.A., MacRae, J., and Hausrath, E.M. 2013. Biogeochemical weathering of serpentinite in batch and flow-through dissolution experiments. Geological Society of America Northeastern Section Meeting, Bretton Woods, NH.

Pavri, F., A. Dailey, P. Bourget, and T. Cole. 2013. Tracking Landscape and Habitat Shifts for the Sebago Lake Region over Two Decades. Maine Water Conference. Augusta, ME.

Peckenham, J. and T. Thornton (2013) Citizen Science Contributions to the Understanding of Well Water Quality. American Water Resources Assoc. Annual Conference, Portland, OR, November 5, 2013

Peckenham, J. (2013). Metrics of source water protection. Sustainable Water Management Conference, American Water Works Association, Nashville, TN, April 8, 2013.

Peckenham, J. (2013). Indicators of groundwater quality: Understanding trends and uncertainty. Maine Water Conference, Augusta, ME, March 19, 2013.

Quartuch, M. 2012. Using Sense of Place and Sense of Community to Understand Landscape Change Behaviors. 2012. Maine EPSCoR Conference. Orono, ME.

Quartuch, Mike. 2013. Attached to What and to Whom: Using Sense of Place and Sense of Community to Examine Forest Landowner Intentions to Parcelize or Develop Private Property. International Symposium on Society and Resource Management, Estes Park Center, CO.

Strock, K.E.D., J.E. Saros, S. Nelson. The effects of extreme climate events on lakewater chemistry: implications for "brownification" in Maine lakes. Maine Water Conference. Augusta, Maine. March 2013.

Strock, K.E.D., J.E. Saros, S.J. Nelson, S.D. Birkel. The effects of extreme climate events on lakewater chemistry: implications for dissolved organic carbon trends in the northeast U.S. American Society of Limnology and Oceanography Meeting. New Orleans, Louisiana. February 2013.

Proceedings

Beard, K. 2012. A Semantic Web-Based Gazetteer Model for VGI. Proceedings of ACM SIGSpatial Workshop, Redondo Beach, CA.

Calhoun, A., J. Jansujwicz, M. Hunter, and K. Bell. Evolving Approaches to Conserving Small Wetlands on Private Lands in the Face of Uncertainty. Proceedings of the National Academy of Science.

Peckenham, J. 2011. Fluoride, Arsenic, and Chloride in Private Water Wells in Eastern Maine. Proceedings of the Private Well Symposium, Southbury, CT.

Reports

Foertsch, I., J.E. Leahy, J.S. Wilson, and R.J. Lilieholm. 2012. Maine's Landowner Survey: Technical Report. Center for Research on Sustainable Forests, University of Maine.

Hutchins, K., L. Thornbrough, L. Finnemore, B. Zollitsch, B. Arter, and L.A. Lindenfeld. Maine Salt Management Taskforce Scoping Project: Technical Report.

Lilieholm, R.J., C.S. Cronan, M.L. Johnson, S.R. Meyer, and D. Owen. 2012. Alternative Futures Modeling in Maine's Penobscot River Watershed: Forging a Regional Identity for River Restoration. Lincoln Institute of Land Policy, Working Paper 12RL1.

Vanderlugt, B., K.P. Bell, A. Frisch, M. Quartuch, and J. Colby-George. 2013. 2012 Maine Landowner Survey: Bangor Metropolitan Area Results.

Vanderlugt, B., K.P. Bell, A. Frisch, M. Quartuch, and J. Colby-George. 2013. 2012 Maine Landowner Survey: Key Findings and Implications for Policy, Outreach, and Landowner Solutions.

Vanderlugt, B., K.P. Bell, A. Frisch, M. Quartuch, and J. Colby-George. 2013. 2012 Maine Landowner Survey: Summary Technical Report.

Poster Presentations

Brown, R.E., Saros, J.E., Nelson, S.J. 2014. Algal community response to increases in dissolved organic carbon over recent decades. Joint Aquatic Sciences Meeting. Portland, Oregon.

Brown, R.E., Saros, J.E., Nelson, S.J. 2014. Algal community response to increases in dissolved organic carbon over recent decades. Maine Water and Sustainability Conference. Augusta, Maine.

Brown, R.E., Saros, J.E., Nelson, S.J. 2013. Algal community response to increases in dissolved organic carbon in Maine lakes: implications for drinking water utilities. 22nd North American Diatom Symposium. Bar Harbor, Maine.

Frisch, A., K. Bell, M. Quartuch, B. Vanderlugt, and J. Colby-George. 2012. Assessing the Concerns of Maine Landowners. Poster presentation at the Maine EPSCoR Conference, Orono, ME.

McGreavy, B. E. Fox, J. Disney, M. Miller, L. Lindenfeld, L. Silka, and C. Petersen. 2013. A Collaborative Model for Conservation Action Planning: Group Communication and Partnership Development for Ecological and Economic Resilience in Frenchman Bay. Poster presentation at the Maine Water Conference, Augusta, ME.

Neville, M. 2013. Mercury (Hg) Research Ontology: Employing Informatics in Geochemistry. Presentations for the National Science Foundation IGERT 2013 Video & Poster Competition. April, 2013.

Neville, M. and Beard, K. 2013. Biogeochemical Informatics for Reuse and Modeling of Legacy Mercury Data. Poster Presentation at the Maine Water Conference, Augusta, ME. March 19, 2013.

Straub, Crista, M. Snell, J. MacRae, A. Reeve, D. Martin, J. Leahy, N. Bird*.* Watershed Model Perceptions In The Sebago Lake Region*.* Poster presentation, Maine Water Conference, March 19, 2013.

Strock, K.E.D., J.E. Saros, S. Nelson. Analyzing legacy data in a climate context to decipher modern changes in lakewater chemistry. BIOGEOMON. Northport, Maine. July 2012.

Thornbrough, Lauren, K. Hutchins, L. Finnemore, L. Lindenfeld, B. Zollitsch. Collaboratively Developing Best Management Practices For Road Salt Application In Maine. Poster presentation, Maine Water Conference, March 19, 2013.

Other Publications

News and Events

We continue to communicate on a regular basis via our “News & Events” publication with our email subscription list of 1,600 contacts using MailChimp. Mailings to the list occur once or twice per month and include short-term news articles, upcoming event information, and other items of interest to our stakeholders and subscribers (15 issued to date in YR5). All articles point to the Mitchell Center website for more in-depth news stories and event information.

A science writer continues to assist the SSI team with various materials that are written for public audiences. This includes news stories, media releases and research project summaries. This allows us to keep our website content fresh and interesting. We also have a student who is working with us on a Faculty Experts Guide and updates to faculty and graduate student profiles. The Faculty Experts Guide is an important addition to our website and provides a one-stop-shop for media interested in connecting with sustainability science research expertise.

doSSIer

doSSIer is the team newsletter of Maine's Sustainability Solutions Initiative, a program of the Mitchell Center. The newsletter is published bi-weekly and provides news and updates for the SSI team. It is e-mailed to 150 participating faculty and students and posted to the SSI web site.

Conferences and Annual Events

Maine Water Conference 2013

The 2013 Maine Water Conference took place on March 19 at the Augusta Civic Center in Augusta, Maine. Sessions topics included groundwater management, environmental education and outreach, fisheries, climate change, non-point source contaminants, river restoration, and more. Plenary speakers were Craig Williamson, Miami University of Ohio, (*Managing Water Resources in a Changing Climate: Deciphering the Sentinel Responses of Lakes in a Warmer and Wetter World)* and Timothy Ford, University of New England (*Global Studies in Water and Health: Implications for Maine).*

The Maine Water Conference is the largest water resources related conference in Maine attracting over 350 water resource professionals. It provides unprecedented opportunities to promote both the Mitchell Center's and UMaine's role in environmental research and problem-solving throughout Maine and to build stronger relationships with state and federal agencies, NGOs, and the private sector. The MWC Steering Committee is made up of key water resource stakeholders from across the state.

Sponsorship for the 2013 Maine Water Conference was provided by: U.S. Geological Survey, Senator George J. Mitchell Center and the Maine Water Institute, Maine's Sustainability Solutions Initiative, Maine WasteWater Control, Maine Geological Survey, Maine Water Utilities Association, Maine Volunteer Lake Monitoring Program, Portland Water District, Maine Water and the Maine Congress of Lake Associations.

Senator George J. Mitchell Lecture on Sustainability

Jane Lubchenco, the first female administrator of the National Oceanic and Atmospheric Administration (NOAA), delivered the 2013 Senator George J. Mitchell Lecture on Sustainability on Sept. 25 at the University of Maine. "Science Serving Society: Achieving Real-World Solutions" was the title of the lecture given by Lubchenco who served as undersecretary of commerce for oceans and atmosphere from 2009 to 2013. In 2013, she returned to Oregon State University, where she is the Wayne and Gladys Valley Professor of Marine Biology and Distinguished Professor of Zoology. Almost 500 people attended the lecture of which ~25% were external constituents and stakeholders. SSI graduate student Bridie McGreavy provided the introduction for Senator George Mitchell at the lecture.

Media/Press

Sustainable Maine

The Maine Public Broadcast Network (MPBN) produced a third season of the Emmy-nominated *Sustainable Maine* with three new episodes featuring the Sustainability Solutions Initiative, a project of the Senator George J. Mitchell Center. http://video.mpbn.net/program/sustainable-maine/

Season 3

- **Return of a River**
  This first episode in this season of the Emmy nominated series features SSI researchers from the University of New England and the Wells National Estuarine Research Reserve, studying the Saco River Estuary. The team is gathering extensive field data from the estuary to develop a grading system to assess the health of the estuary using key indicators that matter to local stakeholders. The team hopes that through active discussion and problem solving the river will remain a vital resource for the community.
- **Culvert Operations**
  Extreme weather costs Maine communities millions of dollars in damage, and many experts predict that it's likely to get worse. Some communities are finding out the hard way that their culverts are no longer big enough to handle the increasing size of floods. It's estimated that there are hundreds of thousands of culverts in Maine, ranging from small drainages under driveways to moose-size culverts under major highways to keep streams and wildlife moving. Failed culverts can disrupt lives and commerce, threaten fragile ecosystems, and quickly swamp municipal budgets. 'Culvert Operations' shows how one research team is working with communities to plan for future extreme weather events.
- **Preserving Paradise**
  The final episode titled "Preserving Paradise" features SSI researchers using new mapping tools and working with stakeholders to allow for "smarter" development across the state. The Alternative Futures Team, based at the University of Maine and University of Maine School of Law, uses focus groups and workshops to help planners and decision-makers figure out what effect the choices they make today may have on the economic, social and environmental future of their communities.

Committees and Service

David Hart

- Member, Science and Technical Advisory Committee, American Rivers
- Member, Sustainable Oceans, Coasts, and Waterways Advisory Committee, Heinz Center for Science, Economics, and the Environment, 2004 – present.
- Member, President's Advisory Committee on Water Information (representing the Ecological Society of America), 2003 – present.

John Peckenham

- Board Member (New England Regional Representative), National Institutes for Water Research.
- New England Private Well Initiative – Water Quality Extension and US EPA Region 1
- Source Water Collaborative and American Water Works Association Source Protection Committee
- New Business Development – Maine Water Security LLC (managing partner), Mainely Sensors

LLC (consultant), Zeomatrix (consultant)

- Penobscot River Keepers
- GET WET!
- River Flow Advisory Commission- Drought Task Force
- Maine Water Conference Organizing Committee
- Maine Water Utilities Association- Water Resources Committee
- Sustainable Water Withdrawal- Land and Water Resources Council
- Maine Waste Water Control Association- Residuals Management Committee
- Penobscot River and Bay Institute- Board of Directors
- Northern Maine Children's Water Festival
- Department of Environmental Protection-Consulting Engineers of Maine Task Force
- New England Water Quality Extension Advisory Board

Sarah Nelson

- Lead scientist, Collaborative Scientific Research program, Old Town High School 2012-2013.
- Panelist, Integrating STEM Education Research into Teaching: Knowledge of Student Thinking--National Conference, June 20-22, 2012. University of Maine, Orono, ME.
- Panelist, Designing effective broader impact projects involving scientists, K-12 teachers and students May 10, 2012, UMaine RiSE Center.
- Convener, Teachers' Data Literacy Workshop at International BIOGEOMON 2012 Conference, Northport, Maine, July 15-20, 2012, in collaboration with S. Norton, I. Fernandez, M. Schauffler, B. Zoellick, H. Webber.
- Lead scientist, Developing indicators for comparative watershed mercury burdens: dragonfly larvae pilot study and citizen science initiative, in cooperation with Colleen Flanagan, NPS-Air Resources Division, Denver, CO, 2011-2012. Thirteen parks across the US are participating.
- Invited participant (of 15), National Park Service and AAAS Scholarly Pursuits Workshop, Yosemite National Park, 19-21 September 2013.
- John Wesley Powell Center Working Group on mercury cycling, bioaccumulation, and risk across North America, participant and invited to author manuscript. 2013-present.
- Steering Committee member, Northeastern Ecosystem Research Cooperative (NERC), 2013 – 2017 term.
- Collaborative research, lead scientist, Old Town High School dragonfly mercury study. School year 2012-2013.
- Convener, Mercury in Acadia and northeast protected areas. In collaboration with NPS-ARD, NPS-Acadia, SERC Instititute
- Lead scientist, Acadia Learning project, 2007-present
- Steering committee member, Acadian Internship in Regional Conservation and Stewardship, 2010-present
- Steering committee member, Downeast and Acadian Inititative, 2010-present
- Maine Water Conference, Science Program Chair, 2010-present
- Acadia Web Portals working group, coordinator, 2009-2010
- Scientist-teacher liaison, Acadia Learning project, 2007-present
- MDI Water Quality Coalition student mentor, 2006-present
- Appalachian Trail Environmental Monitoring Program, Water Quality Working Group

- Coordinator, University of Maine Mercury Research Group, 2006-present
- Board member, Maine Lakes Conservancy Institute 2007 - 2010
- Maine Water Conference Organizing Committee

Other Activities

Maine's Sustainability Solutions Initiative (SSI) at the Mitchell Center

In July 2009, the Senator George J. Mitchell Center was awarded a $20 million, five-year grant by NSF EPSCoR to support Maine's Sustainability Solutions Initiative. With SSI now in its 5th year, synergy between SSI and the Maine WRRI program provides important leveraging opportunities for water resource projects across the state. A key component of the SSI project is its partnership with 12 other educational institutions across Maine. All of these institutions are funded to conduct research under the SSI program – many related to water resources in Maine. WRRI Director John Peckenham acts as liaison between SSI and the partner institutions building relationships that also strengthen the WRRI program. It is also important to note that many faculty who have been funded under the WRRI research program are key collaborators on the SSI project.

Partner institutions include: Bates, Bowdoin, Colby, Unity, University of New England, University of Southern Maine, University of Maine at Farmington, University of Maine at Augusta, University of Maine at Presque Isle, University of Maine at Fort Kent.

Introduction to SSI

Producing knowledge and linking it to actions that meet human needs while preserving the planet's life support systems is emerging as one of the most fundamental and difficult challenges for science in the 21st century. There is growing consensus that traditional methods of generating and using knowledge must be fundamentally reorganized to confront the breadth, magnitude, and urgency of many problems now facing society. Maine's Sustainability Solutions Initiative seeks to transform Maine's capacity for addressing these scientific challenges in ways that directly benefit Maine and other regions. The program of research will also help Maine increase economic activity and technological innovation in ways that sustain the State's remarkable "quality of place".

Research Projects

The following funded projects provide direct linkages with the Maine WRRI program.

- Protecting Natural Resources at the Community Scale: Using vernal pools to study urbanization, climate change and forest management
  Team: University of Maine
  Project range: Statewide
- Sustainable Urban Regions Project
  Team: University of Southern Maine, University of Maine
  Project range: Portland and Bangor
- Decision tools to support water resources sustainability of managed lake systems
  Team: University of Maine, University of Southern Maine
  Project range: Sebago Lake Watershed

- People, Landscape and Communities
  Team: University of Maine
  Project range: Statewide
- The Knowledge-to-Action Collaborative
  Team: University of Maine
  Project range: Statewide
- Analysis of Alternative Futures in the Maine Landscape using Spatial Models of Coupled Social and Ecological Systems
  Team: University of Maine, University of Maine School of Law
  Project range: Lower Penobscot River Watershed & Casco Bay Watershed
- Helping Communities Weather the Storms
  Team: University of Maine, UMaine Cooperative Extension
  Project range: Coastal Maine
- Mobilizing Diverse Interests to Address Invasive Species Threats to Coupled Natural/Human Systems: The Case of the Emerald Ash Borer in Maine
  Team: University of Maine
  Project range: Statewide
- The Maine Tidal Power Initiative: Linking knowledge to action for responsible tidal power development
  Team: University of Maine
  Project range: Down East Maine
- Effects of Climate Change on Organisms
  Team: University of Maine
  Project range: Statewide
- SES Synergy: Finding and Applying Best Practices in Socio-ecological Systems Modeling and Outreach
  Team: University of Maine
  Range: Project wide
- Ecological and Economic Recovery and Sustainability of the Kennebec and Androscoggin Rivers, Estuary and Nearshore Environment
  Team: Bates & Bowdoin Colleges, University of Southern Maine
  Project range: Androscoggin and Kennebec Rivers and Estuary
- Modeling Resilience and Adaptation in the Belgrade Lakes Watershed
  Team: Colby College
  Project range: Belgrade Lakes Watershed
- Sustaining Quality of Place in the Saco River Estuary through Community Based Ecosystem Management
  Team: University of New England
  Project range: Saco River Estuary
- Understanding An Insect Threat to Maine’s Hemlock Trees
  Team: Unity College
  Project range: Southern & Central Maine
- Assessing the Feasibility and Sustainability of Grass Biomass Production in Aroostook County
  Team: University of Maine at Presque Isle (UMPI)
  Project range: Aroostook River Watershed
- Charting the Rangeley Region's Social-Ecological System and Identifying Community Sustainability Strategies

Team: University of Maine at Farmington (UMF)
Project range: Rangeley Lakes Region

- Biomass Energy Resources in the St. John Valley, Aroostook County, Maine: Landscape Implications and Sustainable Development Potentials
  Team: University of Maine at Fort Kent (UMFK)
  Project range: St. John Valley
- Evaluating Interactions Between Wild Turkeys and Maine Agriculture
  University of Maine at Augusta (UMA)
  Project range: Statewide

Mitchell Center and SSI Seminars

- **April 2, 2013** – Vic Sher, Vic Sher Law; *Communicating Science in the Courtroom: What Scientists Need to Know*
- **April 10, 2013** – Robert J. Johnston, Clark University; *Integrating Biophysical and Economic Data for Ecosystem Service Valuation: From Cooling Water to Coastal Flooding.*
- **August 20, 2013** – David Hart, Sustainability Solutions Initiative; *Changing the World, Beginning in Maine.*
- **October 3, 2013 –** Jordan Karubian*; Can Community-Based Partnership Improve the Way We Do Science: A Case Study from a Conservation Hotspot in Ecuador.*
- **October 29, 2013 –** Barry Costa-Pierce, University of New England; *Ecological Aquaculture – The Evolution of the Blue Revolution.*
- **November 15, 2013 –** Mark Lapping, University of Southern Maine; *Can Food Become an Economic Driver for the Maine Economy?*
- **November 19, 2013** – Frank Drummond, University of Maine; *Two Years in…or Even Cowgirls Get the Blues… or the Unhappy Tea Party… or a Glimpse at a Multidisciplinary, Multi-state Pollination Project.*
- **December 3, 2013** – Kohl Kanwit, Maine Dept. of Marine Resources; *Clean Clams – Assessing Human Impacts and Protecting Public Health.*
- **February 10, 2014 –** Ryan Pickering, University of Maine; *The Environment, Outdoor Recreation, and Socioeconomic Status: Current and Future Research within the Sustainability Solutions Initiative.*
- **February 24, 2014 –** Keri Kaczor, Maine Healthy Beaches Program; *Turbulence: Healthy Beaches, Watersheds and Tourist Economies.*

Web Site

A major task has been the establishment of a joint web site for SSI and the Mitchell Center. This site is now live and is available at www.umaine.edu/mitchellcenter. Substantial effort was expended putting together a site plan that provided a detailed roadmap for establishing a single site that combined information from both organizations in a clear and easily navigable format. We also made news updates and event information a priority on the home page to keep the site fresh and informative. The site will require additional work over the summer (2014) as content still needs to be updated and refreshed to fit with the structure of the new center.

Video on Demand
Videos of Mitchell Center seminars, lectures and events are available for viewing on Vimeo. A list of videos is available on the website at:
http://umaine.edu/mitchellcenter/home/news/multimedia/video-on-demand/

New England Sustainability Consortium (NEST)

In fall 2012, UMaine and UNH collaborated on a joint proposal for NSF EPSCoR's RII Track 2 solicitation. The project titled, "*Collaborative Research: Strengthening the scientific basis for decision-making: Advancing sustainability science and knowledge-action capacities in coupled coastal systems*" was approved for funding and started August 1, 2013. One of the key goals of this project is to build a broad sustainability consortium across New England. Many of the faculty participating on this project are members of the SSI team, including two of the new SSI faculty hires Smith and McGill.

Analyzing and Improving Policies, Procedures, and Organizations for the Restoration of River Systems

Mitchell Center/SSI researchers are playing a major role in informing public policies regarding the ecological and economic restoration of the Androscoggin – Kennebec river system. This includes the genesis of a novel boundary organization that serves to link diverse interests and geographies into a common focus. Broad approaches have integrated the study of history, ecology, fisheries management, and land-use management. Stakeholders are co-learning how the unifying theme of a major river drives research to understand the complexity of coupled human-natural systems. Although the boundary organization that is emerging from this project is still forming, significant benefits have already been realized. In terms of connecting the landscape to the river, regional planners and NGOs are now collaborating to shape future land use changes along the river. Fishery scientists have established strong relationships with citizen-scientists to collect quantitative data to evaluate fish-restoration strategies. This has been coupled with a novel analysis of historical fisheries data going back to colonial times that is leading to new theories of connections between the health of ground fisheries and landscape alterations. This work is now driving a broader community conversation that is re-defining how people relate to the river and shoreline settlements. This process is heading towards policies that improve the river system's ecological integrity in ways that will also generate aesthetic and economic benefits.

Mercury Research

Validating Landscape Models for Mercury in Northeast Lakes
Researchers, led by Mitchell Center scientist Sarah Nelson, have been using dragonfly larvae as bio-sentinels – to help understand which types of watersheds and water bodies seem to have greater mercury. This project is studying dragonfly larvae mercury and lake water mercury in a statistical set of lakes across the Northeast (all New England states plus New York).

Dragonfly Larvae Pilot Study
In an effort to increase public awareness regarding mercury, Acadia Learning was expanded in 2012 to collect dragonfly larvae for mercury analysis in national parks. Fourteen national parks across the U.S. are participating in the initial effort. In addition to increasing public awareness about mercury issues, this study provides baseline data to better understand the spatial

distribution of mercury contamination in national parks. The project is led by Sarah Nelson (Mitchell Center) with Colleen Flanagan of the NPS-ARD. Funding is through UMaine's Faculty Research Funds, High End Instrumentation Research (with Clive Devoy, Sawyer Environmental Chemistry Research Lab), and donated time.

The Future of Four Seasons in Maine
Led by Mitchell Center scientist Sarah Nelson, this project engaged 1,275 students and 30 high school teachers with professional scientists in research regarding the changing nature of snowpack across Maine, emphasizing the coastal climate zone where snowmelt provides cues for diadromous fish migration. The project is part of 'Acadia Learning', which provides students with experience of the interconnectedness of coastal watershed systems. The project will produce snow data useful to partners and scientists, who will interact directly with teachers throughout the project. This project is sponsored by the NOAA B-Wet program, which promotes locally relevant, systemic learning about local watershed environments.

Technology Transfer

The Mitchell Center/SSI impact on technology transfer is being achieved in two ways: 1) through the transfer of results to entities in government, tribal communities, the private sector, and non-governmental organizations; and 2) via the adoption of new practices by those organizations. Specific examples of SSI's roles in technology transfer include:

- A collaboration with The Nature Conservancy on the value of "green infrastructure" in Maine provided the opportunity to develop flood hazard models for the Presumpscot River watershed, which will be coupled with Urban Sim to project flood risks.
- A Special Area Management Plan for Vernal Pools has been drafted for adoption by the US Army Corps of engineers; it includes novel mechanisms for mitigation of pool losses.
- Progress has continued on a research model of conservation mechanisms for municipalities that has been framed and modified by stakeholder input.
- Two seasons of documenting the shad run on the Androscoggin River at Brunswick will be used to justify constructing a fish lift suitable for shad to complement the existing fish ladder.
- Research and activities contributed to the development of a national training on Collaborative Learning. This training is being implemented in National Estuarine Research Reserves around the country to build capacity for the Reserves, coastal states and their partners and stakeholders to participate in collaborative research projects designed to sustain ecosystem services and adapt to climate change.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	5	0	0	6	11
Masters	1	0	0	13	14
Ph.D.	2	0	0	11	13
Post-Doc.	0	0	0	5	5
Total	8	0	0	35	43

Notable Awards and Achievements

SSI Research Featured in National Climate Assessment Report

Research being conducted through the Sustainability Solutions Initiative (SSI) was highlighted in the National Climate Assessment report recently released by President Barack Obama, which found global warming is directly affecting life in Maine and other New England states. The research is focused on the effects of increasingly intense and frequent storms striking Maine and New England, causing millions of dollars in damage and threatening fragile ecosystems.

High School Students Conduct Research on Maine s Critical Snowpack

This winter, teams of Maine high school students trudged through harsh conditions to measure snow depths at different sites around the state. Guided by their teachers, the students from Old Town High School and Bangor High School studied the nature of snowpack, snowfall and timing of snowmelt in Maine s various climate zones. The data are of real value to scientists since they have no snow depth/snowmelt information for large swaths of the state.

Funding for this project was provided by the National Oceanic and Atmospheric Administration. Researchers from the Senator George J. Mitchell Center, the Climate Change Institute and the Schoodic Institute at Acadia National Park partnered on the study. Students presented early results of their fieldwork on May 8 at the Acadia Learning Student Research Symposium held at the Mitchell Center. The research was the culmination of partnerships with scientists from the US Geological Survey, Maine Sea Grant and the National Weather Service.

New England SusTainability Consortium (NEST)

In fall 2012, UMaine and UNH collaborated on a joint proposal for NSF EPSCoR's RII Track 2 solicitation. The project titled, Collaborative Research: Strengthening the scientific basis for decision-making: Advancing sustainability science and knowledge-action capacities in coupled coastal systems was approved for funding and started August 1, 2013. One of the key goals of this project is to build a broad sustainability consortium across New England. Many of the faculty participating on this project are members of the SSI team, including two of the new SSI faculty hires Smith and McGill.

The project, titled the New England SusTainability Consortium (NEST) aims to strengthen the scientific basis for decision making related to the management of recreational beaches and shellfish harvesting. This research is a direct outgrowth of the Sustainability Solutions Initiative (SSI).

Sustainable Maine

The Maine Public Broadcast Network (MPBN) produced a third season of the Emmy-nominated Sustainable Maine with three new episodes featuring the Sustainability Solutions Initiative, a project of the Senator George J. Mitchell Center. http://video.mpbn.net/program/sustainable-maine/

Season 3

- **Return of a River**
  This first episode in this season of the Emmy nominated series features SSI researchers from the University of New England and the Wells National Estuarine Research Reserve, studying the Saco

River Estuary. The team is gathering extensive field data from the estuary to develop a grading system to assess the health of the estuary using key indicators that matter to local stakeholders. The team hopes that through active discussion and problem solving the river will remain a vital resource for the community.

- **Culvert Operations**
  Extreme weather costs Maine communities millions of dollars in damage, and many experts predict that it s likely to get worse. Some communities are finding out the hard way that their culverts are no longer big enough to handle the increasing size of floods. It s estimated that there are hundreds of thousands of culverts in Maine, ranging from small drainages under driveways to moose-size culverts under major highways to keep streams and wildlife moving. Failed culverts can disrupt lives and commerce, threaten fragile ecosystems, and quickly swamp municipal budgets. "Culvert Operations" shows how one research team is working with communities to plan for future extreme weather events.
- **Preserving Paradise**
  The final episode titled "Preserving Paradise" features SSI researchers using new mapping tools and working with stakeholders to allow for smarter development across the state. The Alternative Futures Team, based at the University of Maine and University of Maine School of Law, uses focus groups and workshops to help planners and decision-makers figure out what effect the choices they make today may have on the economic, social and environmental future of their communities.

Publications from Prior Years

1. 2012ME260B ("Informatics approaches for reuse and modeling of heterogeneous mercury data") - Other Publications - Neville, M. 2013. Mercury (Hg) Research Ontology: Employing Informatics in Geochemistry. Presentations for the National Science Foundation IGERT 2013 Video & Poster Competition. April, 2013.
2. 2012ME260B ("Informatics approaches for reuse and modeling of heterogeneous mercury data") - Other Publications - Neville, M. and Beard, K. 2013. Biogeochemical Informatics for Reuse and Modeling of Legacy Mercury Data. Poster Presentation at the Maine Water Conference, Augusta, ME. March 19, 2013.
3. 2012ME260B ("Informatics approaches for reuse and modeling of heterogeneous mercury data") - Conference Proceedings - Neville, M. 2012. Informatics Approaches for the Reuse and Modeling of Heterogeneous Mercury Data. National Water Quality Monitoring Council Conference, Portland, OR.
4. 2012ME276B ("Analyzing Legacy Data in a Climate Context to Decipher Modern Changes in Lakewater Chemistry") - Dissertations - Strock, K.E. 2013. Deciphering Climate-Mediated Changes in Boreal Lake Ecosystems. Ph.D. Dissertation, University of Maine, Orono, Maine.
5. 2012ME276B ("Analyzing Legacy Data in a Climate Context to Decipher Modern Changes in Lakewater Chemistry") - Articles in Refereed Scientific Journals - Strock, K.E., S.J. Nelson, J.E. Saros, A. Baumann, J.S. Kahl, W. McDowell. 2014. Trends in biogeochemical recovery from acidification in the Northeastern U.S.: new insights from three decades of lake monitoring. Environmental Science and Technology. Advanced access online: dx.doi.org/10.1021/es404772n
6. 2012ME276B ("Analyzing Legacy Data in a Climate Context to Decipher Modern Changes in Lakewater Chemistry") - Articles in Refereed Scientific Journals - Strock, K.E., S.J. Nelson, S. Birkel, and J.E. Saros. Extreme weather years drive broad episodic changes in lake chemistry: Implications for recovery from sulfate deposition and long-term trends in dissolved organic carbon. Biogeochemistry. In prep.
7. 2011ME236B ("Complex systems assessment of biogeochemical factors and microbial community members associated with naturally occurring uranium contamination in groundwater resources") - Articles in Refereed Scientific Journals - MacRae, J.D. and Mouser, P.J. (in preparation). Changes in microbial communities and geochemistry in groundwater wells with naturally elevated uranium. To be submitted to Journal of Environmental Engineering